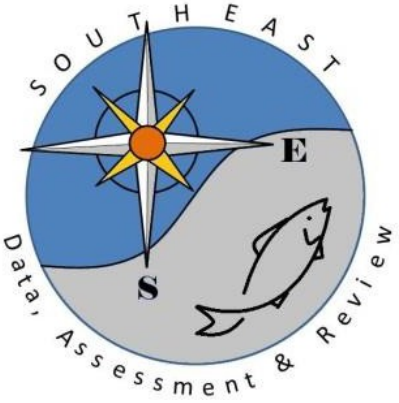

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks

Stock ID Process Final Report

October 2021

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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1. Introduction

1.1 Stock ID Process Summary

The Stock ID Workshop for the four species of Hammerhead shark was held as a series of three webinars, including a data scoping webinar (6/11/2021) and two webinars to discuss data analysis (7/20/2021, 8/10/2021). In an effort to follow best practices in stock identification, an interdisciplinary approach was used to synthesize all available information and determine the most plausible hypotheses of population structure. To that end, information from different approaches (life history, genetics, tagging and movement) was considered and integrated. Most workshop participants volunteered to join one of three designated working groups (WGs): life history, genetics, or spatial distribution/movement. These WGs also met individually outside of the three official Stock ID webinars. Recommendations of the Workshop were formed based on the review and analysis of life history characteristics, genetics, and archival satellite, SPOT (smart position and temperature) transmitting tags, and conventional tagging data. The primary findings of the Stock ID Workshop were as follows.

Regarding Great Hammerhead, the Life History WG determined it was not possible to conclude whether regional differences in life history exist. The Genetics WG found no significant genetic differentiation between the Gulf of Mexico and U.S. Atlantic, and the Spatial Distribution/Movement WG concluded Great Hammerhead comprise a single biological stock based on movements of individuals between regions. The Stock ID Workshop recommended that one stock assessment be conducted for Great Hammerhead.

There were limited data available for assessing the stock identification of Smooth Hammerhead. There are no applicable life history data available and no population genetic studies of Smooth Hammerhead testing for differentiation between locations within U.S. waters. However, both the Life History and Genetics WGs recommended assessing Smooth Hammerheads as a single stock in the U.S. Atlantic and Gulf of Mexico. The Spatial Distribution/Movement WG also agreed that Smooth Hammerheads comprise a single biological stock in the U.S. Atlantic Ocean and Gulf of Mexico based on the fact that they are a wide-ranging species with the ability to move long distances (> 6,600 km; Santos and Coelho, 2018) and it is not inconceivable that this species could occasionally move among regions. The Stock ID Workshop recommended that one stock assessment be conducted for Smooth Hammerhead.

The Carolina Hammerhead is very difficult to distinguish from Scalloped Hammerhead, even for trained biologists, and thus much of the catch data will likely represent both species in unknown overall proportions. There are also very limited data on life history and movements for this species. Based on genetic analysis, Carolina Hammerhead made up 27% of a mixed species sample of these two species in the U.S. Atlantic but was not recorded in a sample from the Gulf of Mexico (Barker et al. 2021). Thus, it is highly likely that Carolina Hammerhead is only found in the U.S. Atlantic. Regarding Scalloped Hammerhead, the Life History WG determined it was not possible to conclude whether regional differences in life history exist. The Genetics WG found no significant genetic differentiation between the Gulf of Mexico and U.S. Atlantic, and the Spatial Distribution/Movement WG concluded Scalloped Hammerheads comprise a single biological stock based on movements of individuals between regions. Considering all of the available information for Carolina and Scalloped Hammerhead, the Stock ID Workshop recommended that two stock assessments be conducted, if sufficient data are available. Carolina and Scalloped Hammerhead

should be assessed as one stock in the U.S. Atlantic and another assessment should be conducted for the Scalloped Hammerhead in the Gulf of Mexico. If it is determined that sufficient data are not available to conduct separate assessments, then a single stock assessment should be conducted for the combined Carolina and Scalloped Hammerhead for all areas in the Northwest Atlantic.

1.2 Workshop Time And Place

The SEDAR 77 HMS Hammerheads Stock ID Process was conducted via a series of webinars, including a data scoping webinar (5/26/2021) and two webinars to discuss data analysis (7/20/2021, 8/10/2021).

1.3 Terms Of Reference

1. Review relevant information on stock structure for all Sphyrna species located in U.S. Atlantic, Gulf of Mexico, and Caribbean, with the exception of S. tiburo, S. tudes, and S. media Potential sources include genetic studies, growth patterns, movement and migration, existing stock definitions, vertebral chemistry, oceanographic and habitat characteristics, and hotspot maps of landings or catch per unit effort (CPUE).

2. Make recommendations on biological stock structure and the assessment unit stock or stocks to be addressed through SEDAR 77, and document the rationale behind the recommendations. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

4. Provide recommendations for future research on stock structure.

5. Prepare a report providing complete documentation of workshop recommendations and decisions.

1.4 List Of Participants

Appointee	Affiliation
Stock ID Panel	
Enric Cortes, analyst	SEFSC Panama City Laboratory
Dean Courtney, analyst	SEFSC Panama City Laboratory
Xinsheng Zhang, analyst	SEFSC Panama City Laboratory
John Carlson, Lead	SEFSC Panama City Laboratory
Heather Baertlein	HMS
Alyssa Mathers	SEFSC Panama City Laboratory
Andrea Kroetz	SEFSC Panama City Laboratory
Cliff Hutt	HMS
Adam Pollack	SEFSC Mississippi Laboratories
Eric Hoffmayer	SEFSC Mississippi Laboratories
Cami McCandless	NEFSC Narragansett Laboratory
Trey Driggers	SEFSC Mississippi Laboratories
Heather Cox	SEFSC Panama City Laboratory
David Wells	Department of Biology Texas A&M University
David Portnoy	Department of Biology Texas A&M University
Bryan Frazier	SC Department of Natural Resources
Robert Latour	Virginia Institute of Marine Science College of William and Mary
R. Dean Grubbs	Florida State University Coastal and Marine Laboratory
Marcus Drymon	Mississippi State University
Bradley Wetherbee	University of Rhode Island
Mahmood Shivji	NOVA Southeastern University - Halmos College of Natural Sciences and Oceanography
Russell Hudson	Directed Shark Fisheries, Inc.
Beth Babcock	RSMAS U. Of Miami
Neil Hammerschlag	RSMAS U. Of Miami
Juan Carlos Perez-Jimenez	El Colegio de la Frontera Sur (ECOSUR)
J. Leonardo Castillo-Geniz	Centro Regional de Investigación Acuícola y Pesquera de Ensenada, BC (CRIAP-Ensenada) del Instituto Nacional de Pesca y Acuacultura (INAPESCA)
Demian Chapman	Mote Marine Laboratory and Aquarium
James Gelsleichter	University of North Florida

List of Participants Cont.	
Other	
Name	**Affiliation**
Michelle Passerotti	NMFS
Kesley Banks	Texas A&M
Steve Durkee	NMFS
Kristin Hannan	NMFS
Mariah Pfleger	Oceana
Bradley Smith	NMFS
Derek Kraft	NMFS
Jayne Gardiner	New College
Gregory Stuntz	Texas A&M Corpus Christi
STAFF Kathleen Howington	SEDAR
Karyl Brewster-Geisz	HMS Management
Margaret Miller	NMFS
Adam Brame	NMFS

1.5 Stock Id Process Working Papers And Reference Documents

Document #	Title	Authors	Received
Documents Prepared for SEDAR 77 Stock ID process			
SEDAR77-SID01	Regional movements of great, *Sphyrna mokarran,* and scalloped, *Sphyrna lewini,* hammerhead sharks in the US Atlantic, Gulf of Mexico and the 2 Bahamas: preliminary results	Vital Heim, Dean Grubbs, Bryan Frazier, Matthew J. Smukall, Tristan L. Guttridge	6/28/2021
SEDAR77-SID02	Catches of Hammerhead Sharks from the Congressional Supplemental Sampling Program (CSSP) in the Northern Gulf of Mexico	Adam G. Pollack and David S. Hanisko	6/29/2021
SEDAR77-SID03	Supplementary Material: Regional movements of great, Sphyrna mokarran, 1 and scalloped, Sphyrna lewini, hammerhead sharks in the US Atlantic,Gulf 2 of Mexico and the Bahamas: preliminary results	Vital Heim, Dean Grubbs, Bryan Frazier, Matthew J. Smukall, Tristan L. Guttridge	6/29/2021
SEDAR77-SID04	Tag and recapture data for Great Hammerhead, *Sphyrna mokarran*, and Scalloped Hammerhead, *Sphyrna lewini*, sharks caught in the western Gulf of Mexico from 2014-2021	Kesley G. Banks, and Gregory W. Stunz	7/2/2021
SEDAR77-SID05	Residency and movements of juvenile great hammerheads, *Sphyrna mokarran*, in the Tampa Bay area: preliminary results	Jayne M. Gardiner, Tonya R. Wiley, Susan K. Lowerre-Barbieri, Kim Bassos-Hull, and Krystan Wilkinson	7/2/2021
SEDAR77-SID06	Directed Sustainable Fisheries, Inc. A Saltwater Fisheries Consulting Company: Some Large Hammerhead shark information based on shark fin business knowledge from the mid-1980's through to September 1997 from Rusty Hudson.	Rusty Hudson	7/5/2021
SEDAR77-SID07	Report on spatial movements of great and scalloped hammerhead sharks in the US Atlantic and Gulf of Mexico using Satellite tags	Neil Hammerschlag	7/14/2021

Document #	Title	Authors	Received
Reference Documents			
SEDAR77-RD01	Movement, Behavior, and Habitat Use of a Marine Apex Predator, the Scalloped Hammerhead	R. J. David Wells, Thomas C. TinHan, Michael A. Dance, J. Marcus Drymon, Brett, Falterman, Matthew J. Ajemian, Gregory W. Stunz, John A. Mohan, Eric R. Hoffmayer, William B. Driggers III and Jennifer A. McKinney	5/27/2021
SEDAR77-RD02	First Verified Record of the Smooth Hammerhead (Sphyrna zygaena) in Coastal Waters of the Northern Gulf of Mexico with a Review of their Occurrence in the Western North Atlantic Ocean	Bethany M. Deacy, Heather E. Moncrief-Cox, and John K. Carlson	5/27/2021
SEDAR77-RD03	Use of marine protected areas and exclusive economic zones in the subtropical western North Atlantic Ocean by large highly mobile sharks	Fiona Graham, Patrick Rynne, Maria Estevanez, Jiangang Luo, Jerald S. Ault and Neil Hammerschlag	5/27/2021
SEDAR77-RD04	Overlap between highly suitable habitats and longline gear management areas reveals vulnerable and protected regions for highly migratory sharks	Hannah Calich, Maria Estevanez, Neil Hammerschlag	5/27/2021

Document #	Title	Authors	Received
Reference Documents Cont.			
SEDAR77-RD05	Regional-scale variability in the movement ecology of marine fishes revealed by an integrative acoustic tracking network	Claudia Friess, Susan K. Lowerre-Barbieri, Gregg R. Poulakis, Neil Hammerschlag, Jayne M. Gardiner, Andrea M. Kroetz, Kim Bassos-Hull, Joel Bickford, Erin C. Bohaboy, Robert D. Ellis, Hayden Menendez, William F. Patterson III, Melissa E. Price, Jennifer S. Rehage, Colin P. Shea, Matthew J. Smukall, Sarah Walters Burnsed, Krystan A. Wilkinson, Joy Young, Angela B. Collins, Breanna C. DeGroot, Cheston T. Peterson, Caleb Purtlebaugh, Michael Randall, Rachel M. Scharer, Ryan W. Schloesser, Tonya R. Wiley, Gina A. Alvarez, Andy J. Danylchuk, Adam G. Fox, R. Dean Grubbs, Ashley Hill, James V. Locascio, Patrick M. O'Donnell, Gregory B. Skomal, Fred G. Whoriskey, Lucas P. Griffin	5/27/2021
SEDAR77-RD06	Restricted connectivity and population genetic fragility in a globally endangered Hammerhead Shark	Danillo Pinhal, Rodrigo R. Domingues, Christine C. Bruels, Bruno L. S. Ferrette, Otto B. F. Gadig, Mahmood S. Shivji, Cesar Martins	5/27/2021

Document #	Title	Authors	Received
Reference Documents Cont.			
SEDAR77-RD07	Tracking the Fin Trade: Genetic Stock Identification in western Atlantic scalloped hammerhead sharks *Sphyrna lewini*	Demian D. Chapman, Danillo Pinhal, Mahmood S. Shivji	5/27/2021
SEDAR77-RD08	Seasonal Movements and Habitat Use of Juvenile Smooth Hammerhead Sharks in the Western North Atlantic Ocean and Significance for Management	Ryan K. Logan, Jeremy J. Vaudo, Lara L. Sousa, Mark Sampson, Bradley M. Wetherbee and Mahmood S. Shivji	5/27/2021
SEDAR77-RD09	The complete mitochondrial genome of the endangered great hammerhead shark, *Sphyrna mokarran*	Cassandra L. Ruck, Nicholas Marra, Mahmood S. Shivji & Michael J. Stanhope	6/18/2021
SEDAR77-RD10	New insights into the migration patterns of the scalloped hammerhead shark *Sphyrna lewini* based on vertebral microchemistry	Claire Coiraton · Felipe Amezcua · James T. Ketchum	6/18/2021
SEDAR77-RD11	Global Phylogeography with Mixed-Marker Analysis Reveals Male-Mediated Dispersal in the Endangered Scalloped Hammerhead Shark (Sphyrna lewini)	Toby S. Daly-Engel, Kanesa D. Seraphin, Kim N. Holland, John P. Coffey, Holly A. Nance, Robert J. Toonen, Brian W. Bowen	6/18/2021
SEDAR77-RD12	Species composition of the largest shark fin retail-market in mainland China	Diego Cardeños, Andrew T. Fields, Elizabeth A. Babcock, Stanley K. H. Shea, Kevin A. Feldheim & Demian D. Chapman	6/18/2021
SEDAR77-RD13	Identification of young-of-the-year great hammerhead shark *Sphyrna mokarran* in northern Florida and South Carolina	A. M. Barker, B. S. Frazier, D. M. Bethea, J. R. Gold and D. S. Portnoy	6/18/2021
SEDAR77-RD14	Sphyrna gilberti sp. nov., a new hammerhead shark (Carcharhiniformes, Sphyrnidae) from the western Atlantic Ocean	Joseph M. Quattro, William B. Driggers Iii, James M. Grady, Glenn F. Ulrich & Mark A. Roberts	6/18/2021

Document #	Title	Authors	Received
Reference Documents Cont.			
SEDAR77-RD16	Philopatry and Regional Connectivity of the Great Hammerhead Shark, Sphyrna mokarran in the U.S. and Bahamas	Tristan L. Guttridge, Maurits P. M. Van Zinnicq Bergmann, Chris Bolte, Lucy A. Howey, Jean S. Finger, Steven T. Kessel, Jill L. Brooks, William Winram, Mark E. Bond, Lance K. B. Jordan, Rachael C. Cashman, Emily R. Tolentino, R. Dean Grubbs and Samuel H. Gruber	6/18/2021
SEDARE77-RD17	Potential distribution of critically endangered hammerhead sharks and overlap with the small-scale fishing fleet in the southern Gulf of Mexico	Mercedes Yamily Chi Chan, Oscar Sosa-Nishizaki, Juan Carlos Pérez-Jiménez	6/23/2021 Revised: 6/29/2021
SEDAR77-RD18	Complete mitogenome sequences of smooth hammerhead sharks, *Sphyrna zygaena*, from the eastern and western Atlantic	Derek S. Guy, Cassandra L. Ruck, Jose V. Lopez & Mahmood S. Shivji	6/18/2021
SEDAR77-RD19	Cryptic hammerhead shark lineage occurrence in the western South Atlantic revealed by DNA analysis	D. Pinhal · M. S. Shivji · M. Vallinoto · D. D. Chapman · O. B. F. Gadig · C. Martins	6/18/2021
SEDAR77-RD20	Double tagging clarifies post-release fate of great hammerheads (Sphyrna mokarran)	J. Marcus Drymon and R. J. David Wells	6/22/2021
SEDAR77-RD21	Defining Sex-Specific Habitat Suitability for a Northern Gulf of Mexico Shark Assemblage	J. M. Drymon, S. Dedman, J. T. Froeschke, E. A. Seubert, A. E. Jefferson, A. M. Kroetz, J. F. Mareska and S. P. Powers	6/22/2021

Document #	Title	Authors	Received
Reference Documents Cont.			
SEDAR77-RD22	Distribution and relative abundance of scalloped (*Sphyrna lewini)* and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean	Amanda M. Barker Bryan S. Frazier, Douglas H. Adams, Christine N. Bedore, Carolyn N. Belcher, William B. Driggers III, Ashley S. Galloway, James Gelsleichter, R. Dean Grubbs, Eric A. Reyier, David S. Portnoy	6/23/2021
SEDAR77-RD23	Distributions and Movements of Atlantic Shark Species: A 52-Year Retrospective Atlas of Mark and Recapture Data	Nancy E. Kohler And Patricia A. Turner	7/6/2021
SEDAR77-RD24	First identification of probable nursery habitat for critically endangered great hammerhead Sphyrna mokarran on the Atlantic Coast of the United States	Catherine Macdonald, Jacob Jerome, Christian Pankow, Nicholas Perni, Kristina Black, David Shiffman, Julia Wester	7/12/2021
SEDAR77-RD25	Characterization of a scalloped hammerhead (Sphyrna lewini) nursery habitat in portions of the Atlantic Intracoastal Waterway	Bryanna N. Wargat	7/15/2021

2. Stock Id Panel Reports

2.1 Life History Working Group

2.1.1 Life History Working Group participants:

William Driggers (National Marine Fisheries Service)
Bryan Frazier (South Carolina Department of Marine Resources)
James Gelsleichter (University of North Florida)
Kristin Hannan (National Marine Fisheries Service)
Heather Moncrief-Cox (National Marine Fisheries Service)
Michelle Passerotti (National Marine Fisheries Service)
Juan Carlos Perez-Jimenez (El Colegio de la Frontera Sur)

2.1.2 Carolina Hammerhead (*Sphyrna gilberti*)

A total of 76 vertebrae (Table 1) were available for construction of growth curves for Carolina hammerheads (all from the Atlantic). Unfortunately, insufficient samples are available to generate robust estimates of growth in this species. The majority of collected specimens to date are young-of-the-year or juvenile animals (Figure 1). Only one mature specimen, a male, was present in the dataset, so reproductive analysis was not conducted on this species. To date, no Carolina hammerheads have been documented in the Gulf of Mexico (Barker et al. 2021). Discussions largely revolved around how the presence of Carolina hammerheads could affect life history data for scalloped hammerheads as Carolina hammerhead specimens are likely present within the available dataset for Atlantic scalloped hammerheads due to the cryptic nature of the species. All specimens used for life history analyses were identified to species using the methods of Barker et al. (2021). Length data from young-of-the-year Carolina and scalloped hammerheads in SC nursery areas suggest Carolina hammerheads are born at a smaller length than scalloped hammerheads (SCDNR unpublished); however, how this difference in length-at-birth impacts species-specific life histories (e.g. growth and fecundity) remains unknown.

2.1.3 Great hammerhead (*Sphyrna mokarran*)

Vertebrae were available from 283 great hammerheads to generate von Bertalanffy growth models to assess if differences existed in growth parameter estimates between individuals collected in United States waters off the east coast (Atlantic) and in the northern Gulf of Mexico (Gulf) (Table 2). The size of sampled great hammerheads ranged from 40.4-357.0 cm fork length (FL) (Table 3).

Ages were obtained using the methods of Piercy et al. (2010) with the exception of no stain (i.e. crystal violet) being used to elucidate growth bands. Band counts were similar between readers with 84% of counts being in agreement. In those cases when counts differed (96% of counts within one year and 100% within two years) consensus was reached on all samples aged. Age and length data were then utilized to generate growth models by sex and region. Likelihood ratio tests (LRT) were used to determine if there were significant differences in growth parameters for great hammerheads among models generated for the Atlantic and Gulf (Cerrato 1990).

Growth parameter estimates and models are presented in Table 4 and Figures 2-4,

respectively. There were significant differences between females (X^2 = 18.79, $p < 0.01$), males (X^2= 22.18, $p < 0.01$) and combined sexes (X^2 = 28.31, $p < 0.01$) between regions (Table 4). As expected, females had higher asymptotic lengths (L_∞) and lower growth constants (k) than males in both regions. However, L_∞ was higher and k was lower in the Gulf than in the Atlantic for both sexes: a general trend not seen in similar species of coastal sharks within the order Carcharhiniformes (e.g. Loefer and Sedberry 2003; Driggers et al. 2004; Frazier et al. 2014). Inspection of the length-at-age data presented in Figures 2 and 3 indicate that smaller size classes (i.e. < 200 cm FL) are underrepresented for both sexes collected in the Atlantic and large individuals are limited, particularly among Gulf samples.

Maturity status information was available for a total of 835 great hammerheads to evaluate length at maturity (Table 5). Of these, the majority of specimens came from the Gulf of Mexico (n=700). No males under 100 cm were available for the Atlantic region, and no females below 200 cm were available (Table 5). Generalized linear models with a logit link and binomial distribution (binary logistic regression models) were fit to the data, and 95% confidence intervals were used to test for significant differences between regions. There was no significant difference in length at 50% maturity (L_{50}) between the Atlantic and Gulf of Mexico, both with sexes combined or independent from one another (Table 6, Figure 5). For age-at-maturity, only 61 had associated ages (Table 7), with no Age-0 individuals present in the dataset, and a higher proportion coming from the Gulf of Mexico. Therefore, additional samples are needed in order to increase confidence in the results presented in Table 8.

While significant differences were found among growth parameters estimated between regions, the Life History Group determined that because data gaps were evident, resulting region-specific growth models need to be further developed through the inclusion of additional samples before it can be reliably determined if regional differences in growth truly exist. As a result, it was concluded that, for the purposes of this assessment, potential differences in the growth of great hammerheads between the Atlantic and Gulf should not be considered when determining stock structure of the species in the western North Atlantic Ocean.

2.1.4 **Scalloped Hammerhead (*Sphyrna lewini*)**

Vertebrae from 945 scalloped hammerheads from fishery dependent and independent sources were available to assess stock structure based on potential life history differences. A total of 631 samples were available from the Atlantic and 286 samples from the Gulf of Mexico, with larger individuals only being represented among Atlantic samples (Table 9). Ages were estimated following the methods of Frazier et al. (2014); however, due to the last-minute inclusion of additional vertebrae, only single-reader age estimates were available at the time of the stock ID workshop.

Estimated age and measured fork lengths (cm) were used to model growth using the von Bertalanffy growth model by sex and region as well as with sexes combined, and sexes and region combined. Likelihood ratio tests (Kimura 1980) were used to test for significant differences between growth models for sexes and regions. Growth parameter estimates and models are presented in Table 10 and Figures 6-8, respectively. There were significant differences in growth between females and males (X^2 = 33.94, $p < 0.01$), therefore, sexes were modeled independently. There were no significant differences in growth for females from the Atlantic and Gulf (X^2 = 2.24, $p < 0.52$); however, given the small sample size from the Gulf (n=105), and lack of samples from large mature

female scalloped hammerheads in this region, we do not have confidence that these results reflect true population parameters. Significant differences in growth were detected for males between regions ($X^2 = 36.83$, $p < 0.01$), with scalloped hammerheads in the Atlantic reaching a larger asymptotic length and having a lower growth constant and older age (Figure 8), similar to trends seen in other coastal sharks (Frazier et al. 2014, Loefer et al. 2003, Vinyard et al. 2020). Despite these differences, it must be noted that there were almost certainly vertebral samples from both Carolina and scalloped hammerheads present in the specimens used to generate growth models for scalloped hammerheads in the Atlantic. Therefore, the growth data generated for the Atlantic could be biased due to potential differences in growth between the two species.

Maturity status information was available for 1,525 scalloped hammerhead specimens, of which 1,038 were captured in the Gulf of Mexico (Table 11). Ages were available for 523 animals to estimate age-at-maturity (Table 13). Generalized linear models with a logit link and binomial distribution (binary logistic regression models) fit to the data showed a significant difference in L_{50} between the Atlantic and Gulf of Mexico with sexes combined, due to a significant difference in males ($L_{50} = 145.87 \pm 1.41$, $p < 0.01$; Table 12, Figure 9). This is likely due to the higher number of immature males in the dataset, primarily from the Atlantic. No significant difference was detected for females between regions ($L_{50} = 178.83 \pm 3.87$, $p < 0.72$). A significant difference between regions was also present for A_{50} with sexes combined ($A_{50} = 12.90 \pm 0.40$, $p < 0.01$; Table 14), again likely due to immature male prevalence in the dataset. No significant difference was detected for females ($A_{50} = 17.44 \pm 1.27$, $p < 0.95$).

Given uncertainties due to sampling (low sample sizes in the GOM, and lack of mature females in both regions), as well as the potentially confounding presence of the Carolina hammerhead, the Life History Group recommended using other data sources (genetic, conventional and electronic tagging data) as primary methods for determining stock structure for scalloped hammerheads. Based on discussions among Life History Working Group members revolving around the presence of Carolina hammerheads in the Atlantic scalloped hammerhead life history samples, it was recommended that the Atlantic and Gulf stocks be assessed separately with the understanding that species-specific life history data is not available for the Carolina Hammerhead.

2.1.5 **Smooth hammerhead (*Sphyrna zygaena*)**

There were no applicable life history data available to determine the stock structure of smooth hammerheads.

2.1.6 **Literature cited**

Barker, A. M., Frazier, B. S., Adams, D. H., Bedore, C. N., Belcher, C. N., Driggers, W. B. III, Galloway, A. S., Gelsleichter, J., Grubbs, R. D., Reyier, E.A., & Portnoy, D. S. 2021. Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean. Fisheries Research 242.

Cerrato, R. M. 1990. Interpretable statistical test for growth comparison using parameters in the von Bertalanffy equation. Canadian Journal of Fisheries and Aquatic Sciences, 47: 1416-1426.

Driggers, W. B. III, Carlson, J. K., Cullum, B. J., Dean, J. M., Oakley, D. & Ulrich, G. F. 2004. Age and growth of the blacknose shark, *Carcharhinus acronotus*, in the western North Atlantic Ocean with comments on regional variation in growth rates. *Environmental Biology of Fishes* 71**:**171–178.

Frazier, B. S., Driggers, W. B. III, Adams, D.H., Jones, C. M., and Loefer, J. K. 2014. Validated age, growth and maturity of the bonnethead *Sphyrna tiburo* in the western North Atlantic Ocean. Journal of Fish Biology 85:688-712.

Kimura, D. K. 1980. Likelihood methods for the von Bertalanffy growth curve. Fisheries Bulletin 77(4): 765-776.

Loefer, J. K. & Sedberry, G. R. 2003. Life history of the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) (Richardson, 1836) off the Southeastern United States. Fishery Bulletin 101**:**75–88.

Piercy, A.N., Carlson, J.K. and Passerotti, M. S. 2010. Age and growth of the great hammerhead shark, *Sphyrna mokarran*, in the north-western Atlantic Ocean and Gulf of Mexico. Marine and Freshwater Research 61:992-998.

2.1.7 **Tables**

Table 1: Sample size and minimum/maximum fork lengths by sex for Carolina hammerheads (*Sphyrna gilberti*) collected off the U.S. east coast (Atlantic).

Sex	n	Min FL (cm)	Max FL (cm)
Female	39	27.0	104.1
Male	37	27.6	192.5
Combined	76	27.0	192.5

Table 2: Sex and capture location of great hammerheads (*Sphyrna mokarran*) specimens used to examine potential growth differences between individuals collected off the U.S. east coast (Atlantic) and in the northern Gulf of Mexico (Gulf).

	Atlantic	Gulf	Areas combined
Female	62	106	168
Male	53	59	112
Sexes combined	115	168	283

Table 3. Fork length (cm) and sex of great hammerheads (*Sphyrna mokarran*) whose vertebrae were utilized to determine if growth differences are present between individuals collected off the east coast (Atlantic) and in the northern Gulf of Mexico (Gulf).

	Atlantic	Gulf
Female	41.7-357.0	54.0-322.0
Male	40.4-296.7	60.0-274.0
Sexes combined	40.4-357.0	55.0-322.0

Table 4. Sex-specific, combined sexes and region-specific von Bertalanffy growth parameter estimates for great hammerheads (*Sphyrna mokarran*) collected off the east coast of the U.S. (Atlantic) and in the northern Gulf of Mexico (Gulf). L_∞ = asymptotic length, k = growth constant, t_o = theoretical age at size zero, MOA = maximum observed age.

Area	Sex	L_∞ (cm)	k	t_o (years)	n	r^2	MOA (years)
Atlantic	Female	316.78	0.13	-1.37	62	0.95	35
	Male	250.84	0.22	-0.86	53	0.96	38
	Combined	281.76	0.17	-1.10	115	0.93	
Gulf	Female	357.37	0.07	-3.50	106	0.92	30
	Male	251.56	0.16	-2.11	59	0.92	34
	Combined	298.00	0.11	-2.80	168	0.90	
Combined	Female	327.42	0.10	-2.12	168	0.93	
	Male	250.29	0.19	-1.34	112	0.93	
	Combined	286.99	0.14	-1.74	283	0.91	
Piercy et al. (2010)	Female	307.8	0.11	-2.86	105	0.85	44
	Male	264.2	0.16	-1.99	111	0.92	42
	Combined	286.9	0.13	-2.51	216	0.89	

Table 5. Sex, capture location, maturity status and fork lengths used to evaluate potential differences in length-at-maturity for great hammerhead (*Sphyrna mokarran*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	Immature	2	207.0	214.5	222	48.0	222.0	224	48.0	222.0
	Mature	11	228.0	309.0	107	118.7	360.0	118	118.7	360.0
	Combined	13	207.0	309.0	329	48.0	360.0	342	48.0	360.0
Male	Immature	31	100.0	225.0	255	50.0	221.0	286	50.0	225.0
	Mature	91	117.0	291.0	116	108.0	340.4	207	108.0	340.4
	Combined	122	100.0	291.0	371	50.0	340.4	493	50.0	340.4
Combined	Immature	33	100.0	225.0	477	48.0	222.0	510	48.0	225.0
	Mature	102	117.0	309.0	223	108.0	360.0	325	108.0	360.0
	Combined	135	100.0	309.0	700	48.0	360.0	835	48.0	360.0

Table 6. Great hammerhead (*Sphyrna mokarran*) sex-specific, combined sex and region-specific lengths at which 50% of the specimens were mature (L_{50}), with minimum and maximum fork lengths (FL) reported.

	Sex	L_{50}	Min FL (cm)	Max FL (cm)
Atlantic	Female	209.63	207.0	309.0
	Male	189.52	100.0	291.0
	Combined	188.70	100.0	309.0
Gulf of Mexico	Female	196.21	48.0	360.0
	Male	201.74	50.0	340.4
	Combined	199.64	48.0	360.0
Combined	Female	196.79	48.0	360.0
	Male	198.57	50.0	340.4
	Combined	197.58	48.0	360.0

Table 7. Sex, capture location, maturity status and estimated ages used to evaluate potential differences in age-at-maturity for great hammerhead (*Sphyrna mokarran*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)
Female	Immature	2	7	9	10	2	9	12	2	9
	Mature	4	11	32	14	4	17	18	4	32
	Combined	6	7	32	24	2	17	30	2	32
Male	Immature	4	6	9	15	3	14	19	3	14
	Mature	7	10	20	5	10	25	12	10	25
	Combined	11	6	20	20	3	25	31	3	25
Combined	Immature	6	6	9	25	2	14	31	2	14
	Mature	11	10	32	19	4	25	30	4	32
	Combined	17	6	32	44	2	25	61	2	32

Table 8. Great hammerhead (*Sphyrna mokarran*) sex-specific, combined sex and region-specific ages at which 50% of the specimens were mature (A_{50}), along with minimum and maximum ages observed for individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

	Sex	A_{50}	Min Age (yr)	Max Age (yr)
Atlantic	Female	10.2	7	32
	Male	9.4	6	20
	Combined	9.6	6	32
Gulf of Mexico	Female	6.5	2	17
	Male	12.3	3	25
	Combined	8.9	2	25
Combined	Female	7.1	2	32
	Male	11.0	3	25
	Combined	9.1	2	32

Table 9. Sex and capture location of scalloped hammerhead (*Sphyrna lewini*) specimens used to examine potential growth differences between individuals collected off the U.S. east coast (Atlantic) and in the northern Gulf of Mexico. A limited number of individuals (n=11 Female, n=17 Male) had no known region and are included in the areas combined only.

	Atlantic			Gulf of Mexico			Areas Combined		
Sex	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	243	31.6	245.0	105	30.0	235.0	359	30.0	245.0
Male	388	30.8	287.0	181	35.0	223.0	586	30.8	287.0
Combined	631	30.8	287.0	286	30.0	235.0	945	30.0	287.0

Table 10. Sex-specific, combined sexes and region-specific von Bertalanffy growth parameter estimates for scalloped hammerheads (*Sphyrna lewini*) collected off the east coast of the U.S. (Atlantic) and in the northern Gulf of Mexico (Gulf). L_∞ = asymptotic length, k = growth constant, t_o = theoretical age at size zero, MOA = maximum observed age.

Region	Sex	L_∞ (cm)	k	t_0 (years)	n	MOA
Atlantic	Female	277.2	0.05	-3.31	243	31.0
	Male	247.4	0.07	-2.48	388	41.9
	Combined	256.4	0.06	-2.78	631	41.9
Gulf	Female	263.8	0.06	-2.97	105	29.7
	Male	212.8	0.10	-1. 90	181	34.1
	Combined	223.9	0.09	-2.19	286	34.1
Combined	Female	280.5	0.05	-3.21	359	31.0
	Male	234.6	0.08	-2.28	586	41.9
	Combined	246.0	0.07	-2.88	945	41.9
Piercy	Female	233.1	0.09	-1.62	116	30.5
	Male	214.8	0.13	-2.22	191	30.5
	Combined	219.8	0.12	-1.84	307	30.5

Table 11. Sex, capture location, maturity status and fork lengths used to evaluate potential differences in length-at-maturity for scalloped hammerhead (*Sphyrna lewini*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	Immature	99	31.6	196.0	288	31.0	182.9	387	31.0	196.0
	Mature	33 6	188.0	243.0	35	177.0	255.0	68	177.0	255.0
	Combined	13 2	31.6	243.0	323	31.0	255.0	455	31.0	255.0
Male	Immature	15 6	31.8	183.0	392	28.0	192.0	548	28.0	192.0
	Mature	19 9	149.3	250.0	323	110.0	289.0	522	110.0	289.0
	Combined	35 5	31.8	250.0	715	28.0	289.0	107 0	28.0	289.0
Combined	Immature	25 5	31.6	196.0	680	28.0	192.0	935	28.0	196.0
	Mature	23 2	149.3	250.0	358	110.0	289.0	590	110.0	289.0
	Combined	48 7	31.6	250.0	103 8	28.0	289.0	152 5	28.0	289.0

Table 12. Scalloped hammerhead (*Sphyrna lewini*) sex-specific, combined sex and region-specific lengths at which 50% of the specimens were mature (L_{50}), with minimum and maximum fork lengths (FL) reported.

	Sex	L_{50}	Min FL (cm)	Max FL (cm)
Atlantic	Female	177.59	31.6	243.0
	Male	157.11	31.8	250.0
	Combined	159.85	31.6	250.0
Gulf of Mexico	Female	180.43	31.0	255.0
	Male	141.76	28.0	289.0
	Combined	145.22	28.0	289.0
Combined	Female	178.83	31.0	255.0
	Male	145.87	28.0	289.0
	Combined	149.66	28.0	289.0

Table 13. Sex, capture location, maturity status and estimated ages used to evaluate potential differences in age-at-maturity for scalloped hammerhead (*Sphyrna lewini*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)
Female	Immature	99	0	22	53	0	20	152	0	22
	Mature	13	7	24	1	10	10	14	7	24
	Combined	112	0	24	54	0	20	166	0	24
Male	Immature	138	0	17	52	0	21	190	0	21
	Mature	104	9	42	63	8	34	167	8	42
	Combined	242	0	42	115	0	34	357	0	42
Combined	Immature	237	0	22	105	0	21	342	0	22
	Mature	117	7	42	64	8	34	181	7	42
	Combined	354	0	42	169	0	34	523	0	42

Table 14. Scalloped hammerhead (*Sphyrna lewini*) sex-specific, combined sex and region-specific ages at which 50% of the specimens were mature (A_{50}), along with minimum and maximum ages observed for individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

	Sex	A_{50}	Min Age (yr)	Max Age (yr)
Atlantic	Female	17.4	0	24
	Male	12.7	0	42
	Combined	13.7	0	42
Gulf of Mexico	Female	17.7	0	20
	Male	10.2	0	34
	Combined	10.7	0	34
Combined	Female	17.4	0	24
	Male	11.9	0	42
	Combined	12.9	0	42

2.1.8 **Figures**

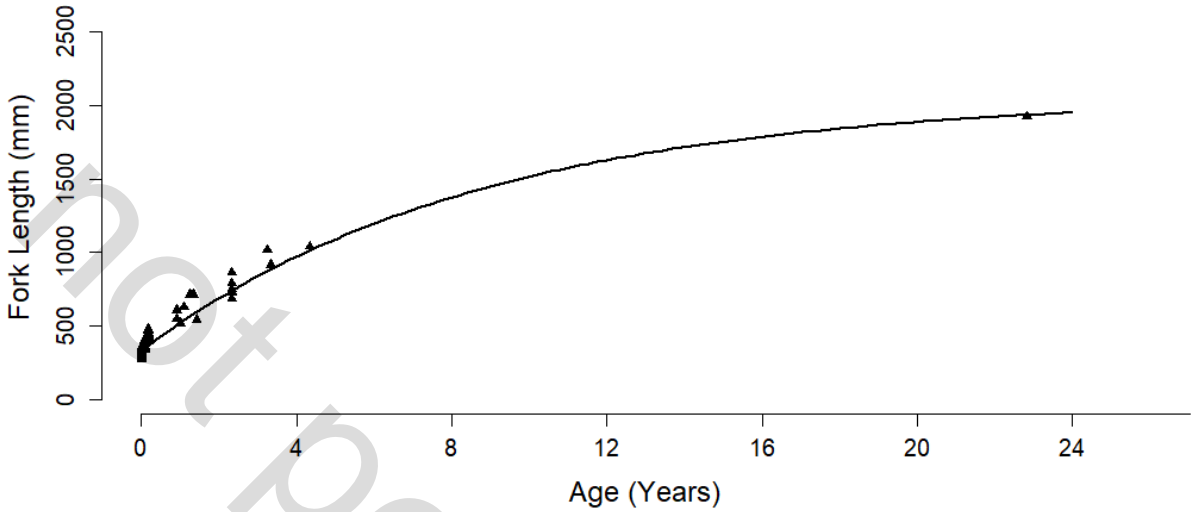


Figure 1. von Bertalanffy growth curve for combined male and female Carolina hammerheads (*Sphyrna gilberti*) sampled off the east coast of the U.S. (Atlantic).

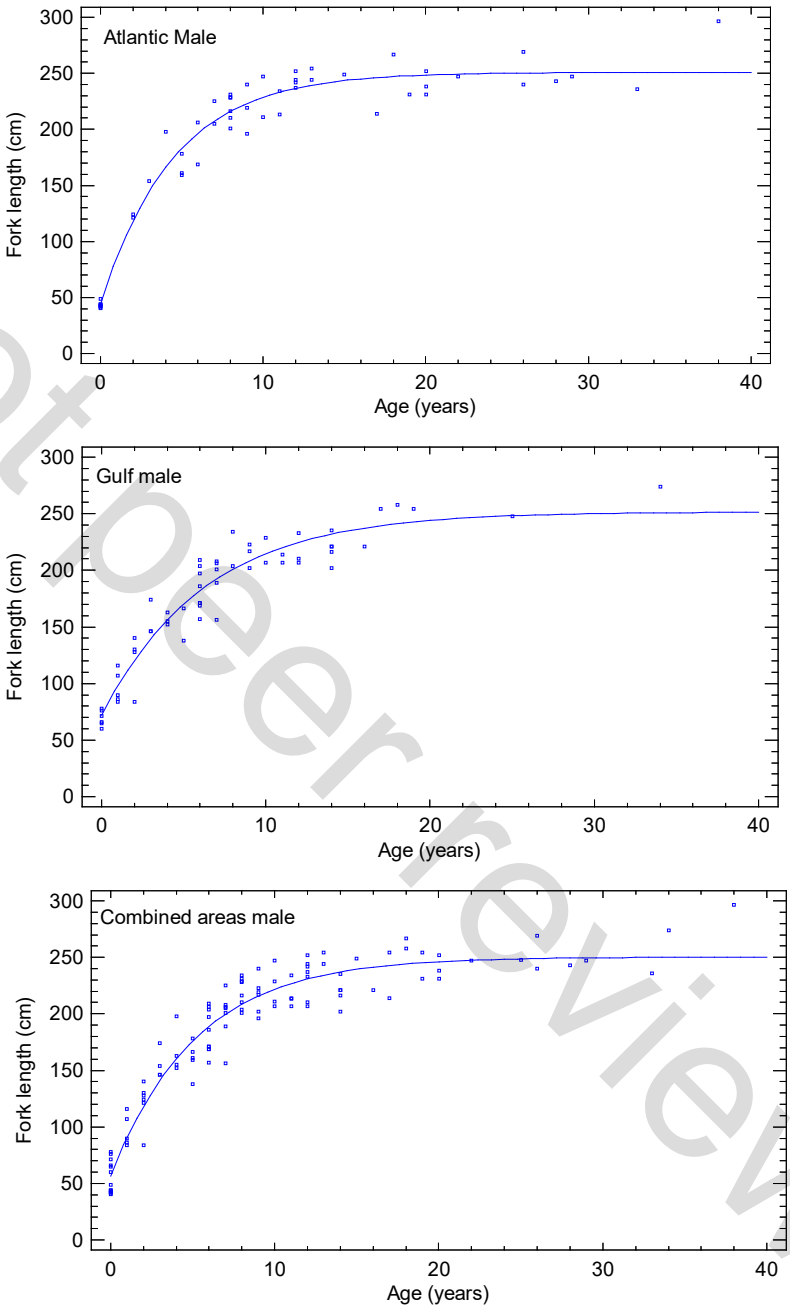


Figure 2. von Bertalanffy growth curves for male great hammerheads (*Sphyrna mokarran*) sampled off the east coast of the U.S. (Atlantic), the northern Gulf of Mexico (Gulf), and regions combined.

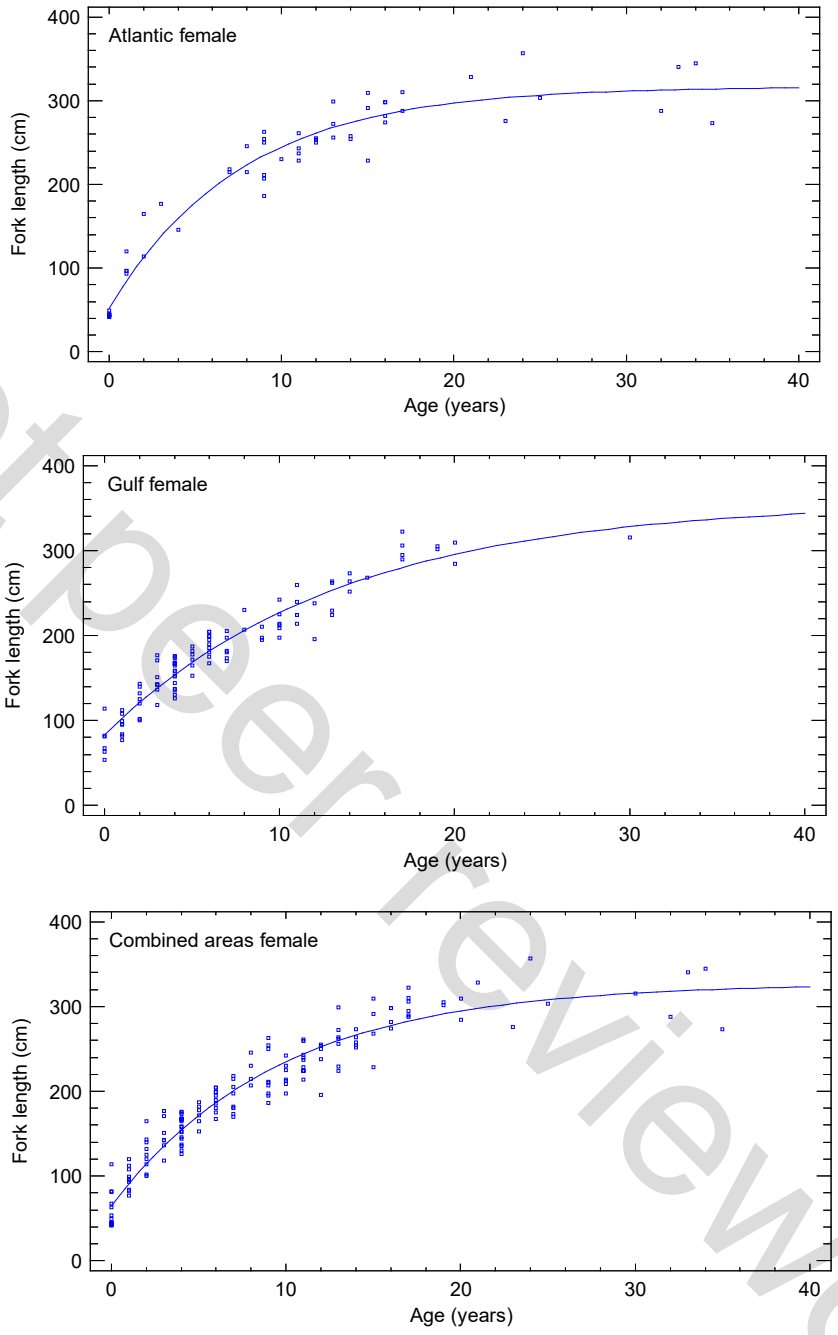


Figure 3. von Bertalanffy growth curves for female great hammerheads (*Sphyrna mokarran*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico (Gulf), and regions combined.

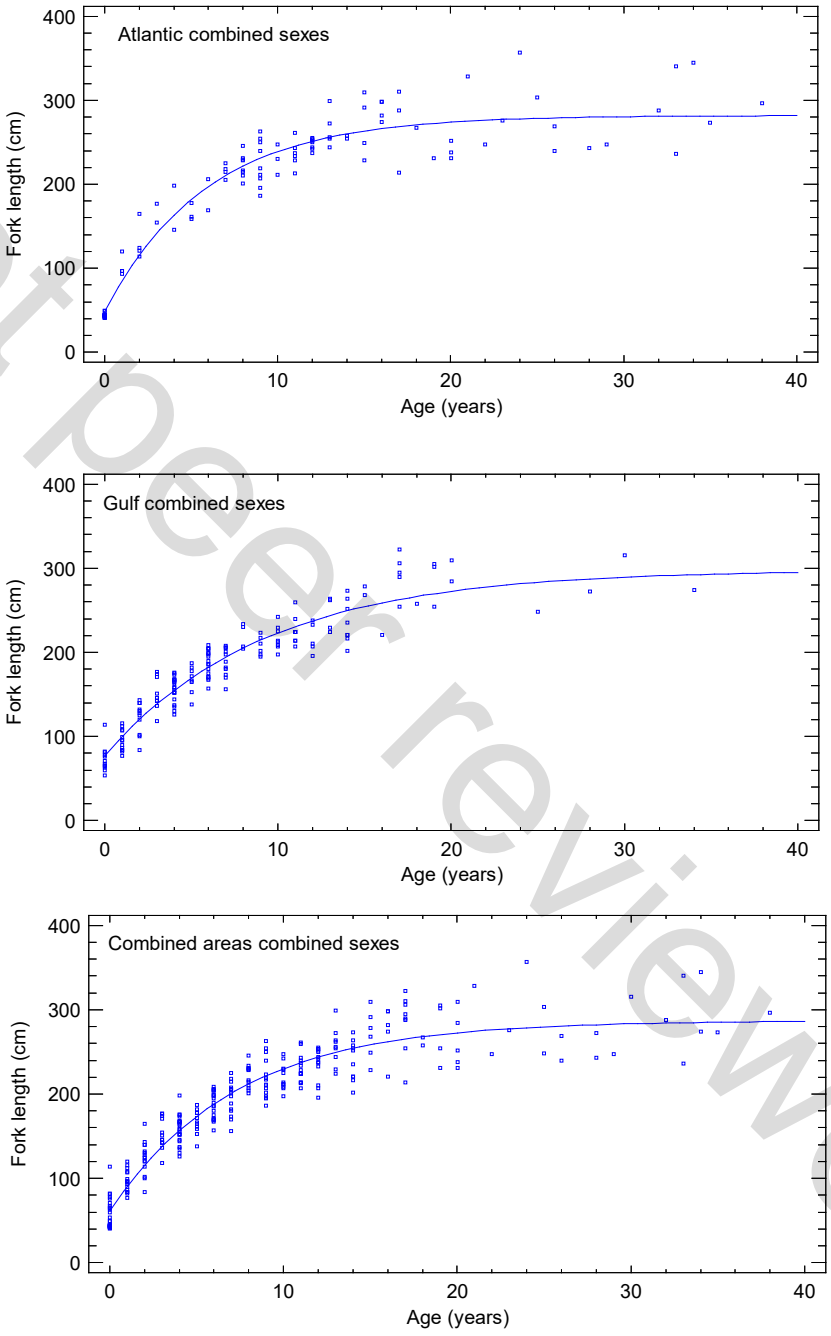


Figure 4. von Bertalanffy growth curves for male and female great hammerheads (*Sphyrna mokarran*) combined sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico (Gulf), as well as regions combined.

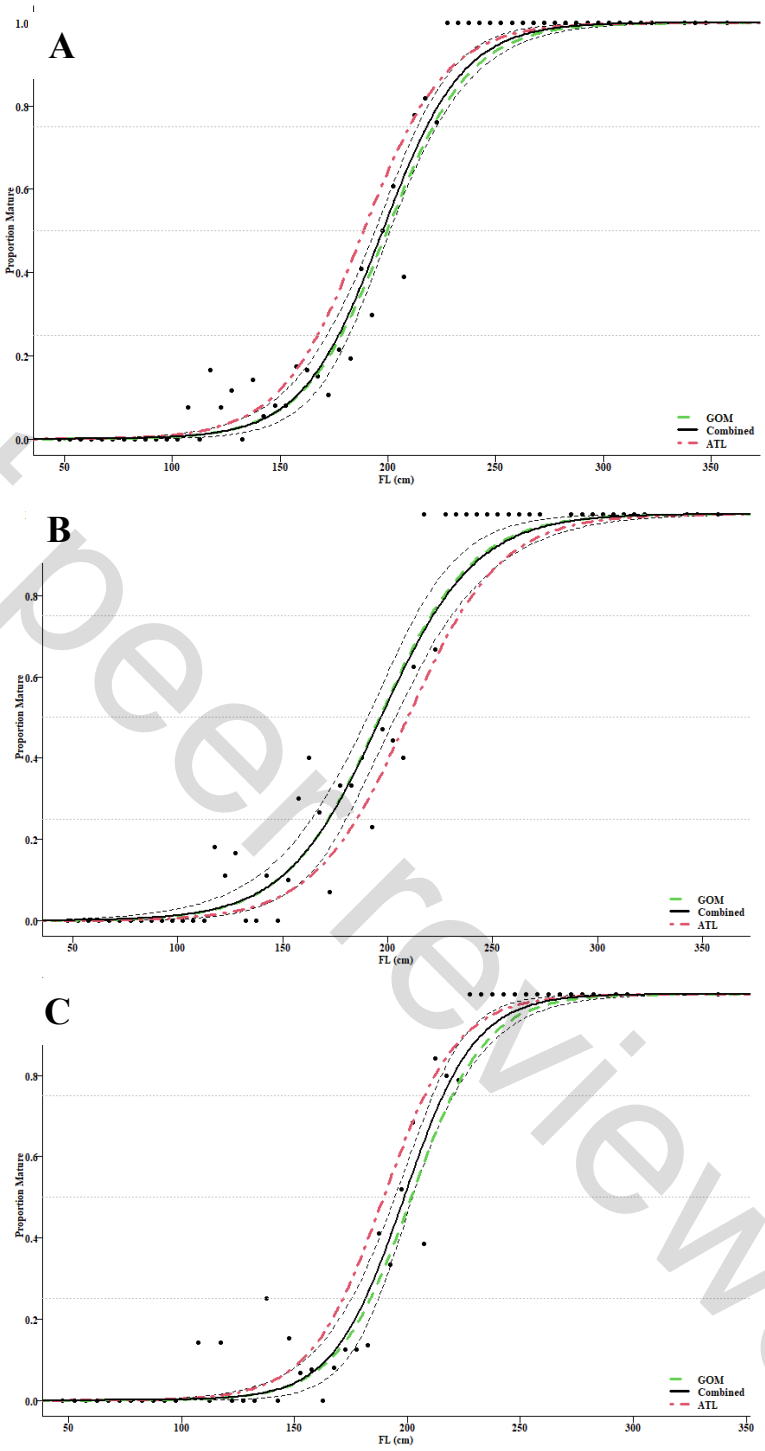


Figure 5. Proportion mature at length for great hammerhead (*Sphyrna mokarran*) maturity data for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line. Black dashed lines represent 95% confidence intervals from bootstrap analysis.

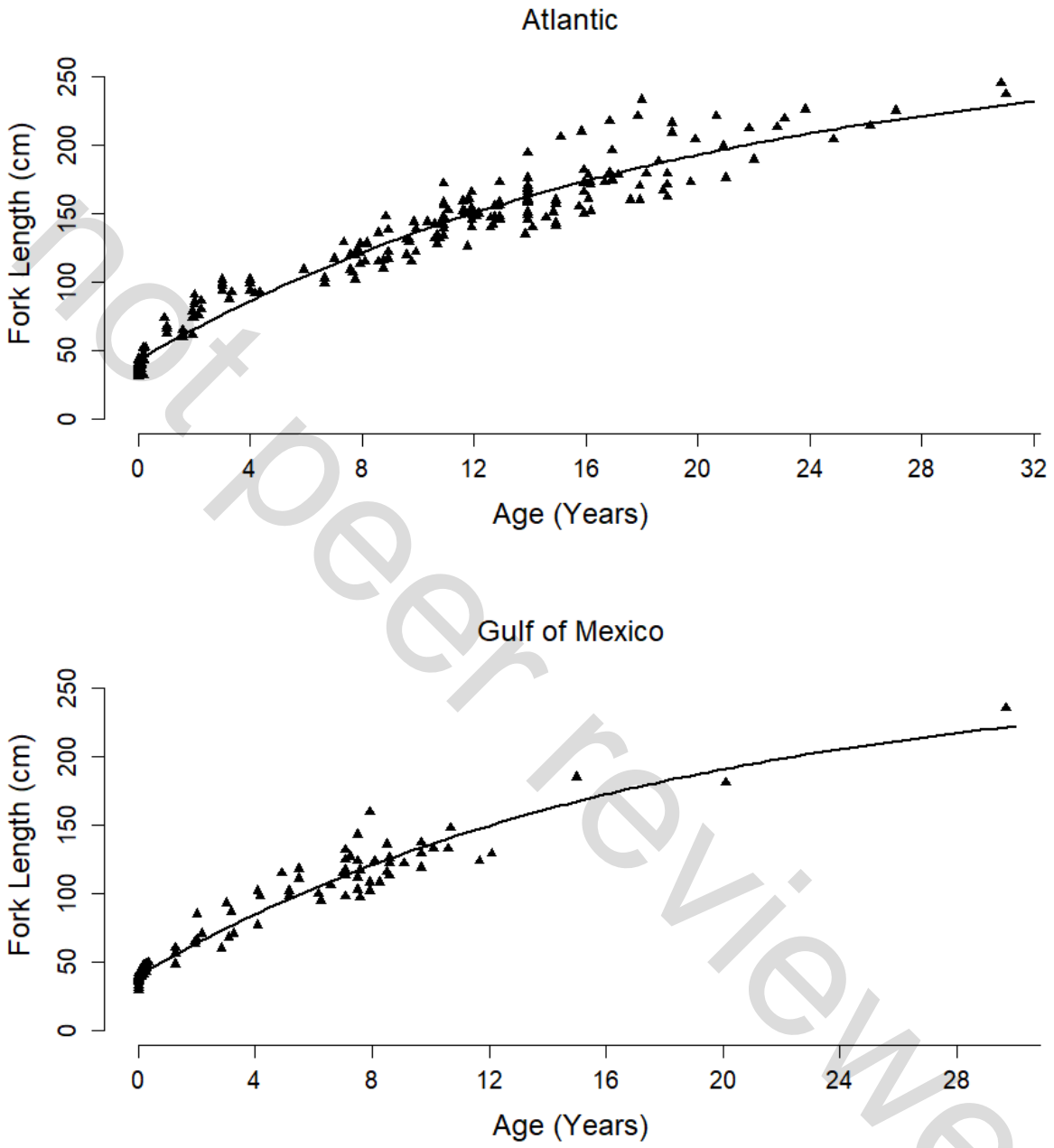


Figure 6. von Bertalanffy growth curve for female scalloped hammerheads (*Sphyrna lewini*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico.

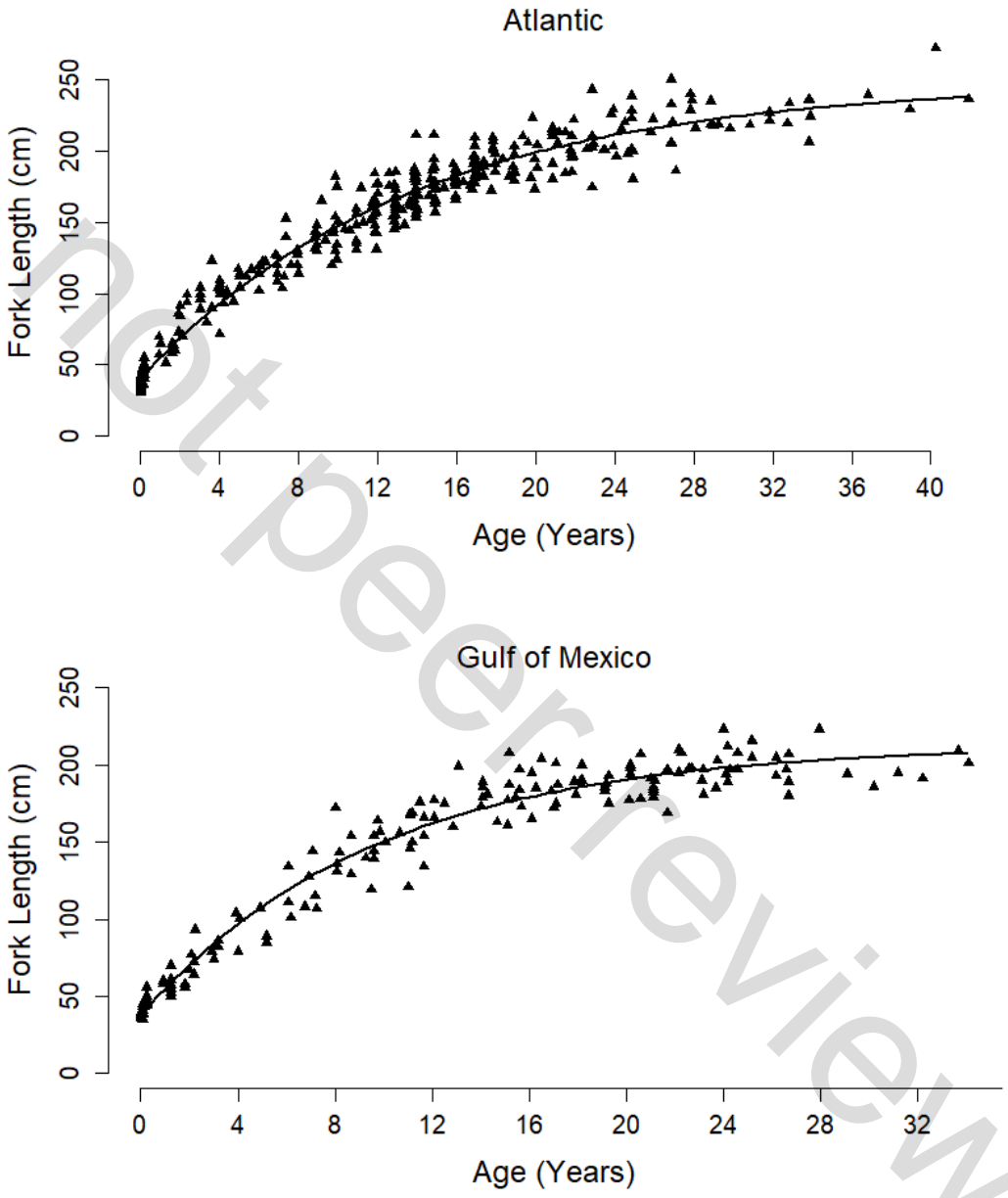


Figure 7. von Bertalanffy growth curves for male scalloped hammerheads (*Sphyrna lewini*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico.

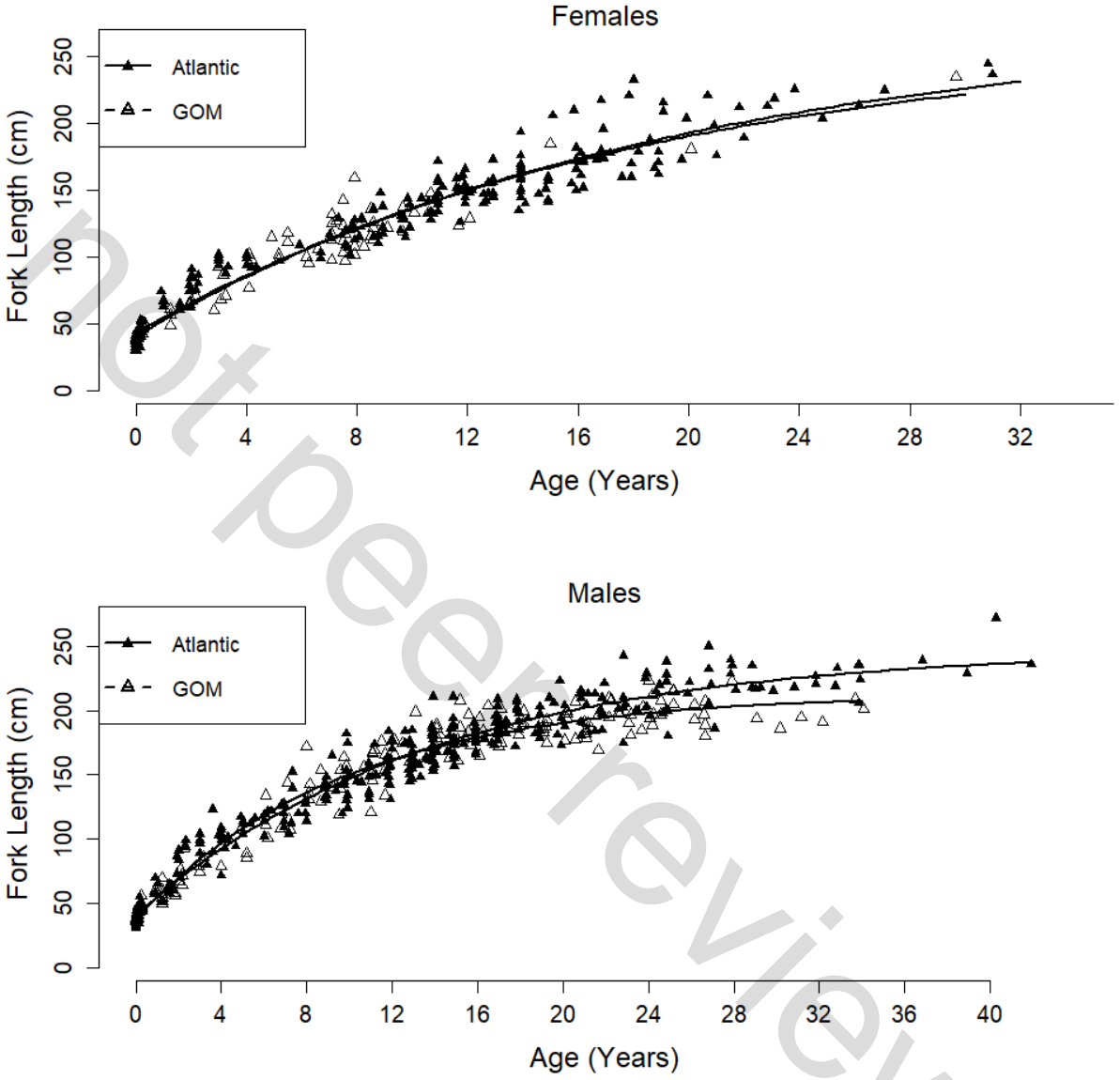


Figure 8. Comparison von Bertalanffy growth curves for female and male scalloped hammerheads (*Sphyrna lewini*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico (GOM).

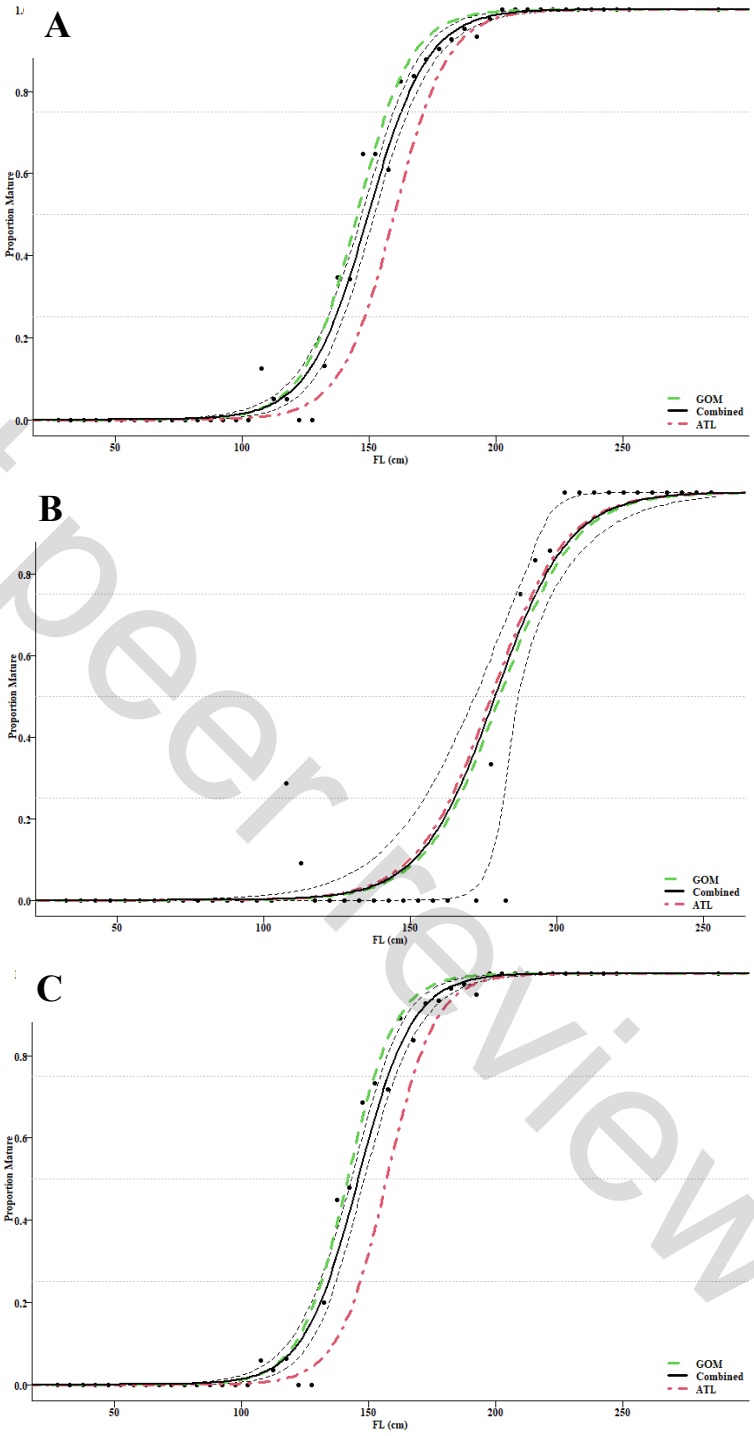


Figure 9. Proportion mature at length for scalloped hammerhead (*Sphyrna lewini*) maturity data for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line. Black dashed lines represent 95% confidence intervals from bootstrap analysis.

2.2 Genetics Working Group

2.2.1 **Review relevant information on stock structure.**

Genetics Workgroup Appointed Participants: Demian Chapman (Mote Marine Laboratory & Aquarium), Mahmood Shivji (Nova Southeastern University), Derek Kraft (NOAA Fisheries), David Portnoy (Texas A & M University).

Literature and Data Review and Evaluation: The genetics working group reviewed published literature relevant to the genetic population structure of four species of hammerhead sharks in U.S. Atlantic, U.S. Gulf of Mexico and U.S. Caribbean jurisdictions during a Zoom videoconference and via email. They also discussed some unpublished data that were relevant.

Working documents that were reviewed by the workgroup included the following publications and theses (in chronological order by publication date):

- Duncan, K.M., Martin, A.P., Bowen, B.W. and De Couet, H.G., 2006. Global phylogeography of the scalloped hammerhead shark (*Sphyrna lewini*). Molecular ecology, 15(8), pp.2239-2251.
- Chapman, D.D., Pinhal, D. and Shivji, M.S., 2009. Tracking the fin trade: genetic stock identification in western Atlantic scalloped hammerhead sharks *Sphyrna lewini*. Endangered Species Research, 9(3), pp.221-228.
- Pinhal, D., Shivji, M.S., Vallinoto, M., Chapman, D.D., Gadig, O.B.F. and Martins, C., 2012. Cryptic hammerhead shark lineage occurrence in the western South Atlantic revealed by DNA analysis. Marine Biology, 159(4), pp.829-836.
- Daly-Engel, T.S., Seraphin, K.D., Holland, K.N., Coffey, J.P., Nance, H.A., Toonen, R.J. and Bowen, B.W., 2012. Global phylogeography with mixed-marker analysis reveals male-mediated dispersal in the endangered scalloped hammerhead shark (*Sphyrna lewini*). PLoS One, 7(1), p.e29986.
- Testerman, C.B., 2014. Molecular Ecology of Globally Distributed Sharks. Doctoral dissertation. Nova Southeastern University. Retrieved from NSUWorks, Oceanographic Center. https://nsuworks.nova.edu/occ_stuetd/6.
- Barker, A.M., Adams, D.H., Driggers III, W.B., Frazier, B.S. and Portnoy, D.S., 2019. Hybridization between sympatric hammerhead sharks in the western North Atlantic Ocean. Biology letters, 15(4), p.20190004.
- Pinhal, D., Domingues, R.R., Bruels, C.C., Ferrette, B.L., Gadig, O.B., Shivji, M.S. and Martins, C., 2020. Restricted connectivity and population genetic fragility in a globally endangered Hammerhead Shark. Reviews in Fish Biology and Fisheries, 30, pp.501-517.
- Barker, A.M., Frazier, B.S., Adams, D.H., Bedore, C.N., Belcher, C.N., Driggers III, W.B., Galloway, A.S., Gelsleichter, J., Grubbs, R.D., Reyier, E.A. and Portnoy, D.S., 2021. Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean. Fisheries Research, 242, p.106039.

2.2.2 **Smooth Hammerhead (*Sphyrna zygaena*)**

There are no population genetic studies of Smooth Hammerhead sharks testing for differentiation between locations within U.S. jurisdictions. This species exhibits an anti-tropical distribution in the Atlantic and the species core U.S. distribution appears to be at higher latitudes in the U.S. Atlantic with rare records in the Gulf of Mexico and the U.S. Caribbean (Rigby, C.L. *et al*. 2019. *Sphyrna zygaena*. The IUCN Red List of Threatened Species 2019: e.T39388A2921825. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39388A2921825.en). The U.S. Atlantic population is differentiated from populations in the Southwest Atlantic based on complete mt control region sequences (U.S. Atlantic (n=21) and Southwest Atlantic (Brazil, n=55; pairwise Φ_{ST} = 0.1116, $P < 0.0001$) but not microsatellites (Testerman 2014).

Recommendation: The working group recommends assessing Smooth Hammerheads as one stock in the U.S. Atlantic (core U.S. range) and U.S. Gulf of Mexico. We caution that no sampling or analyses included U.S. Caribbean jurisdictions (Puerto Rico and U.S. Virgin Islands). We also recommend sampling efforts to determine if Smooth Hammerheads occur in the U.S. Caribbean jurisdictions and, if so, determine whether or not they are genetically differentiated from the core U.S. Atlantic population.

2.2.3**Great Hammerhead (*Sphyrna mokarran*)**

A large sample of mostly large juvenile and adult Great Hammerheads from the U.S. Atlantic, U.S. Gulf of Mexico, Bahamas, and Belize has been tested with multiple genetic markers (mitochondrial control region, microsatellites, and SNPs) by Nova Southeastern University and Texas A & M University. There was no significant differentiation observed in any comparison (Testerman 2014;, 3,873 SNP-containing loci in examined in a U.S. Atlantic sample [N=24] and U.S. Gulf of Mexico sample [N=218] exhibited non-significant F_{ST} [0.0003, P=0.1568]).

Recommendation: The working group recommends assessing Great Hammerheads as one stock in the U.S. Atlantic, U.S. Gulf of Mexico and broader Caribbean region, although we caution that no sampling or analyses included U.S. Caribbean jurisdictions. We recommend sampling and genetic analyses from the U.S. Caribbean jurisdictions. We also recommend sampling and genetic analysis of young-of-the year and small juvenile (< 110 cm total length) individuals because the current sample is dominated by individuals in the mobile phase of their life-cycle, which could mask structure based on reproductive philopatry.

2.2.4 **Carolina Hammerhead (*Sphyrna gilberti*)**

The Carolina Hammerhead occurs in sympatry with its morphologically indistinguishable sister species the Scalloped Hammerhead in the U.S. Atlantic, with a core distribution around Bulls Bay, South Carolina (Barker et al. 2021). Carolina Hammerheads made up 27% of a mixed species sample of these two species in the U.S. Atlantic but was not recorded in a sample from the Gulf of Mexico (Barker et al. 2021). The species has also been recorded in the Caribbean (Trinidad and Tobago, Portnoy unpublished data) and Southwest Atlantic (Brazil; Pinhal et al. 2012) but these specimens have not been genetically compared to U.S. specimens. The species has not yet been recorded in U.S. Caribbean jurisdictions.

Recommendation: The working group recommends assessing Carolina Hammerheads as one stock in the U.S. Atlantic (core U.S. range). We caution that no sampling or analyses included U.S. Caribbean jurisdictions. We recommend sampling efforts to determine if Carolina Hammerheads occur in the U.S. Caribbean jurisdictions and, if so, determine whether or not they are genetically differentiated from the core U.S. Atlantic population.

2.2.5 **Scalloped Hammerhead (*Sphyrna lewini*)**

A large sample of Scalloped Hammerheads from the U.S. Atlantic, U.S. Gulf of Mexico, Belize and Brazil has been tested with multiple genetic markers (mitochondrial control region and 10 microsatellites [N=308], or SNPs [N=679]) (Duncan et al. 2006, Chapman et al. 2009, Daly-Engel et al. 2012, Pinhal et al. 2020, Portnoy unpublished data). Mitochondrial control region sequences and 10 microsatellite loci separate at least three differentiated stocks across this range, with the U.S. Atlantic and U.S. Gulf of Mexico forming one stock and Belize and Brazil each comprising separate stocks with unclear boundaries due to a lack of samples from elsewhere (Chapman et al. 2009, Pinhal et al. 2020; mitochondrial control $\Phi_{ST} = 0.60$; $P < 0.001$, microsatellites: D_{EST} 0.0794, $P < 0.001$). Daly-Engel et al. 2012 recorded differentiation between Scalloped Hammerhead samples from the U.S. Atlantic (N= 29) and U.S. Gulf of Mexico (N=43) using 13 microsatellite loci ($F_{ST} = 0.07$, $P < 0.001$) but subsequent SNP analyses with a larger sample size (N= 679), more markers (4,415 SNP-containing loci) and after filtering out within-sample siblings, found no evidence of population differentiation ($F_{ST} = 0.0000$, $P = 0.5144$).

Recommendation: The working group recommends assessing Scalloped Hammerheads as one stock in the U.S. Atlantic and U.S. Gulf of Mexico. We cautiously recommend assessing Scalloped Hammerheads in U.S. Caribbean jurisdictions separately. Although a sample exists from Puerto Rico (N=7 individuals) it has not yet been analyzed. The Scalloped Hammerheads in the Western Caribbean (Belize) are differentiated from U.S. Atlantic and U.S. Gulf of Mexico and we think the same is likely to be true for Eastern Caribbean populations. We recommend genetic analyses of U.S. Caribbean Scalloped Hammerheads as a matter of urgency given that the Central & Southwest Atlantic Distinct Population Segment (DPS) of this species is listed under the Endangered Species Act (https://www.federalregister.gov/documents/2014/07/03/2014-15710/endangered-and-threatened-wildlife-and-plants-threatened-and-endangered-status-for-distinct).
The working group also recommends that if the Scalloped and Carolina hammerheads cannot be separately assessed that they should be assessed as a complex, recognizing that catches of the complex in the U.S. Atlantic are more likely to contain both species than catches of the complex in the U.S. Gulf of Mexico (which will be comprised solely or primarily of scalloped hammerheads). This could entail managing the Scalloped hammerhead/Carolina hammerhead as a complex in the U.S. Atlantic and the Scalloped hammerhead in the U.S. Gulf of Mexico.

2.3 Spatial-Movements and Catches Working Group

. Introduction

2.3.1 **Workshop Time And Place**

The SEDAR 77 HMS Atlantic Hammerhead Stock ID Process was conducted via a series of webinars, including a Data Scoping webinar (May 26, 2021) and two Stock ID webinars (July 20, 2021; August 10, 2021).

2.3.2 **Terms Of Reference**

Process Goal: Review hammerhead shark species stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the South Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

1. Review relevant information on stock structure for all *Sphyrna* species located in the U.S. Atlantic, Gulf of Mexico, and Caribbean Sea, with the exception of *S. tiburo*, *S. tudes*, and *S. media.* Potential data sources include genetic studies, growth patterns, movement and migration, existing stock definitions, vertebral chemistry, oceanographic and habitat characteristics, and hotspot maps of landings or catch per unit effort (CPUE).

2. Make recommendations on biological stock structure and the assessment unit stock or stocks to be addressed through SEDAR 77, and document the rationale behind the recommendations. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

4. Provide recommendations for future research on stock structure.

5. Prepare a report providing complete documentation of workshop recommendations and decisions.

2.3.3 **Spatial Working Group Participants**

Panelists	**Affiliation**
Andrea Kroetz (Co-Chair, Movements/Satellite tagging)	CIMAS/SEFSC Panama City
Eric Hoffmayer (Co-Chair, Movements/Satellite tagging)	SEFSC Pascagoula
Cami McCandless (Co-Chair, Movements/Conventional tagging)	NEFSC Narragansett
Enric Cortes (Co-Chair, Catches)	SEFSC Panama City
Heather Baertlein	ECS/HMS
Marcus Drymon	Mississippi State University
R. Dean Grubbs	Florida State University
Neil Hammerschlag	University of Miami
Cliff Hutt	HMS
Adam Pollack	SEFSC Pascagoula
David Wells	Texas A&M Galveston
Bradley Wetherbee	University of Rhode Island

Contributors	**Affiliation**
Kesley Banks	Texas A&M Corpus Christi
Jayne Gardiner	New College
Juan Carlos Pérez Jiménez	El Colegio de la Frontera Sur
Gregory Stunz	Texas A&M Corpus Christi

2.3.4 **Spatial Movements And Catches Working Papers And Reference Documents**

Document #	Title	Authors
Spatial Working Documents Prepared for the Stock ID Workshop (SID)		
SEDAR77-SID01	Regional movements of great, *Sphyrna mokarran*, and scalloped, *Sphyrna lewini*, hammerhead sharks in the US Atlantic, Gulf of Mexico and the Bahamas: preliminary results	V Heim, RD Grubbs, B Frazier, MJ Smukall, and TL Guttridge
SEDAR77-SID02	Catches of hammerhead sharks from the Congressional Supplemental Sampling Program (CSSP) in the northern Gulf of Mexico	AG Pollack and DS Hanisko
SEDAR77-SID03	Supplementary Material: Regional movements of great, *Sphyrna mokarran*, and scalloped, *Sphyrna lewini*, hammerhead sharks in the US Atlantic,Gulf of Mexico and the Bahamas preliminary results	V Heim, RD Grubbs, B Frazier, MJ Smukall, and TL Guttridge
SEDAR77-SID04	Tag and recapture data for great hammerhead, *Sphyrna mokarran*, and scalloped hammerhead, *Sphyrna lewini*, sharks caught in the western Gulf of Mexico from 2014-2021	KG Banks, and G W Stunz
SEDAR77-SID05	Residency and movements of juvenile great hammerheads, *Sphyrna mokarran*, in the Tampa Bay area preliminary results	JM Gardiner, TR Wiley, SK Lowerre-Barbieri, K Bassos-Hull, and K Wilkinson
SEDAR77-SID06	Some large hammerhead shark information based on shark fin business knowledge from the mid-1980's through to September 1997	R Hudson
SEDAR77-SID07	Report on spatial movements of great and scalloped hammerhead sharks in the US Atlantic and Gulf of Mexico using satellite tags	N Hammerschlag

Spatial Reference Documents (RD)		
SEDAR77-RD01	Movement, behavior, and habitat use of a marine apex predator, the scalloped hammerhead	RJD Wells, TC TinHan, MA Dance, JM Drymon, B Falterman, MJ Ajemian, GW Stunz, JA Mohan, ER Hoffmayer, WB Driggers III and JA McKinney
SEDAR77-RD02	First verified record of the smooth hammerhead (*Sphyrna zygaena*) in coastal waters of the northern Gulf of Mexico with a review of their occurrence in the western North Atlantic Ocean	BM Deacy, HE Moncrief-Cox, and JK Carlson
SEDAR77-RD03	Use of marine protected areas and exclusive economic zones in the subtropical western North Atlantic Ocean by large highly mobile sharks	F Graham, P Rynne, M Estevanez, J Luo, JS Ault1 and N Hammerschlag
SEDAR77-RD04	Overlap between highly suitable habitats and longline gear management areas reveals vulnerable and protected regions for highly migratory sharks	H Calich, M Estevanez, and N Hammerschlag
SEDAR77-RD05	Regional-scale variability in the movement ecology of marine fishes revealed by an integrative acoustic tracking network	C Friess, SK Lowerre-Barbieri, GR Poulakis, N Hammerschlag, JM Gardiner, AM Kroetz, K Bassos-Hull, et al.
SEDAR77-RD08	Seasonal movements and habitat use of juvenile smooth hammerhead sharks in the western North Atlantic Ocean and significance for management	RK Logan, JJ Vaudo, LL Sousa, M Sampson, B M Wetherbee and MS Shivji
SEDAR77-RD13	Identification of young-of-the-year great hammerhead shark *Sphyrna mokarran* in northern Florida and South Carolina	AM Barker, BS Frazier, DM Bethea, JR Gold, and DS Portnoy

SEDAR77-RD16	Philopatry and regional connectivity of the great hammerhead shark in the US and Bahamas	TL Guttridge, MPM Van Zinnicq Bergmann, C Bolte, LA Howey, JS Finger, ST Kessel, JL Brooks, W Winram, ME Bond, LKB Jordan, RC Cashman, ER Tolentino, RD Grubbs and SH Gruber
SEDAR77-RD17	Potential distribution of critically endangered hammerhead sharks and overlap with the small-scale fishing fleet in the southern Gulf of Mexico	MY Chi Chan, O Sosa-Nishizaki, JC Pérez-Jiménez
SEDAR77-RD20	Double tagging clarifies post-release fate of great hammerheads	JM Drymon and RJD Wells
SEDAR77-RD21	Defining sex-specific habitat suitability for a northern Gulf of Mexico shark assemblage	JM Drymon, S Dedman, JT Froeschke, EA Seubert, AE Jefferson, AM Kroetz, JF Mareska, and SP Powers
SEDAR77-RD22	Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean	AM Barker BS Frazier, DH Adams, CN Bedore, CN Belcher, WB Driggers III, AS Galloway, J Gelsleichter, RD Grubbs, EA Reyier, DS Portnoy
SEDAR77-RD23	Distributions and movements of Atlantic shark species: A 52-year retrospective atlas of mark and recapture data	NE Kohler and PA Turner
SEDAR77-RD24	First identification of probable nursery habitat for critically endangered great hammerhead *Sphyrna mokarran* on the Atlantic Coast of the United States	C Macdonald, J Jerome, C Pankow, N Perni, K Black, D Shiffman, J Wester
SEDAR77-RD25	Characterization of a scalloped hammerhead (*Sphyrna lewini*) nursery habitat in portions of the Atlantic Intracoastal Waterway	BN Wargat

2.3.5 **Literature And Data Evaluation**

The Spatial-Movements Working Group reviewed 22 relevant working papers and reference documents that described movements and distributions of great (*Sphyrna mokarran*), scalloped (*S. lewini*), Carolina (*S. gilberti*), and smooth (*S. zygaena*) hammerheads. Extensive review of the literature was conducted to locate information regarding movements from satellite, acoustic, and mark-recapture tagging. Limited information was available for all species. A recommendation for stock boundary based on these documents is provided.

SEDAR77-SID01 and SEDAR77-SID03 (supplementary to SID01)
Titles: Regional movements of great, *Sphyrna mokarran*, and scalloped, *Sphyrna lewini*, hammerhead sharks in the US Atlantic; Gulf of Mexico and the Bahamas: preliminary results
Synopsis: In this study, 15 great hammerhead (*Sphyrna mokarran*) and 10 scalloped hammerhead (*Sphyrna lewini*) sharks were tagged with fin-mounted Smart Position and Temperature tags (SPOT, Wildlife Computers) between January 2019 and June 2021 to track their large-scale movements. Tagging efforts were in the Bahamas (Bimini and Andros Island), Florida Keys (FL, USA), South Carolina (USA), and Tampa (FL, USA) and the estimated battery duration ranged from 171 to 300 days. Fourteen great hammerheads generated data and days at liberty ranged from 37 to 286 days. The sharks showed a high degree of individual variation in their regional movements and migrations. While some sharks migrated up and down the US Atlantic coast, others swam into the Gulf of Mexico, and two males tagged in the Bahamas predominantly spent time in the Bahamas EEZ. Eight scalloped hammerheads generated regional movement data and days at liberty ranged from 10 to 404 days. Individual sharks tagged in South Carolina showed relatively similar movement patterns spatially and timing-wise with movement further north during the summer months and movements back down south towards South Carolina in autumn. One female that was pregnant at the time of capture showed a large-scale movement from the Florida Keys to Louisiana, back to the Florida Keys and then north along the US Atlantic coast to South Carolina. This study provides useful data on the large-scale movements of both great and scalloped hammerheads, although the sample sizes are small and these data are preliminary. These data indicate exchange between the Gulf of Mexico and Atlantic in both species.

SEDAR77-SID02
Title: Catches of hammerhead sharks from the Congressional Supplemental Sampling Program (CSSP) in the northern Gulf of Mexico
Synopsis: The Congressional Supplemental Sampling Program (CSSP), also referred to as Expanded Annual Stock Assessment (EASA) program in previous SEDAR documents, was a single year, highly extensive survey that sampled the northern Gulf of Mexico (GOM). The CSSP was intended to provide additional information on key fisheries in the GOM, create a truly synoptic survey, increase precision of relative abundance estimates, and to evaluate selectivity issues between gears and hook sizes. Four longline and two vertical line vessels simultaneously fished randomly selected sites in the northern GOM from April 7 – October 25, 2011. For this document, all stations from the CSSP, along with the catches of great hammerhead (*Sphyrna mokarran*) and scalloped hammerhead (*Sphyrna lewini*) were extracted from the Mississippi Laboratories Oracle Database. Overall, 1,172 bottom longline stations were sampled from April through October. Scalloped

hammerheads were more prevalent in the sampling than great hammerheads, with 140 and 24 individuals being captured, respectively. Higher catches of great hammerheads occurred off the Texas and Louisiana coastlines whereas scalloped hammerheads had higher catches offshore of Texas, Louisiana, Mississippi, and Alabama. Although for only one year (2011), these data are useful in showing distribution for great and scalloped hammerheads throughout the Gulf of Mexico.

SEDAR77-SID04
Title: Tag and recapture data for great hammerhead, *Sphyrna mokarran*, and scalloped hammerhead, *Sphyrna lewini*, sharks caught in the western Gulf of Mexico from 2014-2021.
Synopsis: In partnership with the Center for Sportfish Science and Conservation, anglers participating in the Texas Shark Rodeo (TSR) target sharks from shore using large reels and baits. The anglers practice catch-photo-release with an "emphasis on tagging and collecting data for the conservation of sharks". From 2014 - June 2021, 46 great hammerheads and 39 scalloped hammerheads were tagged and released. Of the 46 great hammerhead sharks tagged, there were three reported recaptured, one of which was recaptured twice within a month. Of the 39 scalloped tagged, two recaptures were reported. All movements were considered short distance (4 out of 5 sharks moved >85 km), except for one scalloped hammerhead that was recaptured and landed in Carbajal, Mexico (~400 km).

SEDAR77-SID05
Title: Residency and movements of juvenile great hammerheads, *Sphyrna mokarran*, in the Tampa Bay area preliminary results
Synopsis: This pilot study was carried out to examine the spatiotemporal patterns of habitat use in the Tampa Bay estuary by juvenile great hammerheads (*Sphyrna mokarran*). Four juveniles captured via longline gear were tagged with surgically-implanted acoustic transmitters (V16-4L and V9-2L, Innovasea), two in 2019 and two in 2020. Upon release, their movements within the Tampa Bay and Sarasota Bay areas were tracked by arrays of passive acoustic receivers maintained by the authors. Detection data from receivers in other areas were obtained via collaborative telemetry networks, Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) and the FACT Network. Detection data are current through spring (May/June) 2021 for the New College of Florida/Havenworth Coastal Conservation and Sarasota Coast Acoustic Network arrays and through summer 2020 for the Florida Fish and Wildlife Conservation Commission arrays. Detection data were filtered to remove false detections and residency indices at the regional (Tampa Bay, Sarasota Bay, Gulf of Mexico) level were computed. All four great hammerheads displayed residency in Tampa Bay. The smallest individual, a 1.3m male, also exhibited residency in Sarasota Bay. All individuals were seasonally present in the Tampa Bay estuary (or Sarasota Bay estuary) during spring/summer and moved out into the Gulf of Mexico during late fall to winter, returning inshore in spring. Movement maps indicate that the smallest individual was detected primarily in inshore areas, while larger individuals were detected in deeper offshore areas, with the largest individual venturing the furthest from Tampa Bay. All four individual great hammerheads were found to use the Tampa Bay estuary for extended periods and to return to the same areas across multiple years. These data are preliminary, as tags are still active and data for movements within and outside the Tampa Bay area continue to be received as arrays are downloaded, but they provide further evidence of a potential nursery area in lower Tampa Bay.

SEDAR77-SID06
Title: Some large hammerhead shark information based on shark fin business knowledge from the mid-1980's through to September 1997
Synopsis: Rusty Hudson provided a summary of hammerhead shark information on catch composition and identification he gained from buying, and/or selling shark fins from various commercial fishing fleets located from New York to Texas during the mid-1980's through 1997. With respect to catches he reports that the frequency of encounter for primary shark fins was greatest for the scalloped hammerhead, followed by the great hammerhead, though the weight of the set of primary shark fins for the great hammerhead are much larger than any other adult hammerhead. Additionally, the smooth hammerhead was third by number with catch generally coming from commercial shark fishing fleets of different sorts between NC and Florida east coasts, and adult catch coming from offshore where the pelagic longline fleets operated off the US east coast. He also reports rare encounters with Carolina hammerhead fins that he thinks were from sharks caught offshore.

SEDAR77-SID07
Title: Report on spatial movements of great and scalloped hammerhead sharks in the US Atlantic and Gulf of Mexico using satellite tags
Synopsis: This report plots SPOT tag movement data on great and scalloped hammerheads showing movement between the Gulf of Mexico and Atlantic. These plots were not shown in the publications associated with this work, which are included as reference documents for this Stock ID Workshop (SEDAR77-RD03 and SEDAR77-RD04).

SEDAR77-RD01
Title: Movement, behavior, and habitat use of a marine apex predator, the scalloped hammerhead
Synopsis: The goal of this study was to better understand the movement dynamics of this species in the Gulf of Mexico. The scalloped hammerhead (Sphyrna lewini) was the first shark species to be protected under the U.S. Endangered Species Act and has life history characteristics that make this species particularly at risk for local depletion. A total of 33 scalloped hammerheads were tagged with fin mounted smart position and temperature transmitting (SPOT) tags and tracked for an average of 146 days (ranging from 5 to 479 days) to examine horizontal movements and quantify space use. Scalloped hammerheads showed a wide range of movements throughout the Gulf of Mexico continental shelf with limited long-distance dispersal. No individuals left the Gulf of Mexico. Habitat suitability for scalloped hammerheads was predicted to be high on the mid to outer continental shelf inside the 200 m isobath. Findings from this study provide important information on movement of this species in the Gulf of Mexico and highlight their restricted use of continental shelf habitat and resident behavior that will need to be incorporated in future stock assessments and extinction risk analyses.

SEDAR77-RD02
Title: First verified record of the smooth hammerhead (*Sphyrna zygaena*) in coastal waters of the northern Gulf of Mexico with a review of their occurrence in the western North Atlantic Ocean
Synopsis: This study documents a confirmed record of smooth hammerhead (*Sphyrna zygaena*) in the northern Gulf of Mexico. Smooth hammerheads are considered a wide-ranging species, though its distribution throughout its range is not well known. The occurrence of this species in the northern Gulf of Mexico is largely unknown, with only limited unverified records in this region. In

September of 2017, a smooth hammerhead was collected from Florida coastal waters in the northern Gulf of Mexico, representing a confirmed record of this species in this region. To further understand the range of smooth hammerhead, available occurrence data throughout the western North Atlantic Ocean was reviewed. At-sea observer data from 1996–2018 in the pelagic longline fishery that targets swordfish *(Xiphias gladius)* and tuna (*Thunnus* sp.) contained 8 records of smooth hammerheads in deep offshore waters, mostly in the southern Gulf of Mexico. Additionally, data collected by observers from the commercial shark bottom longline fishery since 1994 reported 6 smooth hammerhead captures in the Straits of Florida. In the western North Atlantic Ocean, the smooth hammerheads' distribution is not well known. A review of available records showed that sightings are limited, and available data comes generally from commercial fishery catch data, recreational fishing reports, historical reports, and reports through citizen science organizations. The majority of these records occurred in the deep offshore waters beyond the continental shelf, and there appears to be a trend of habitat usage that suggests this species tends to occur in offshore pelagic waters along the continental shelf. The occurrences from observer data in the Gulf of Mexico suggest this species may follow the deep waters of the shelf in this region as well. Given the highly migratory nature of other closely related hammerhead shark species, these reports could suggest that the Smooth Hammerhead migrates along the edge of the continental shelf off the east coast of the United States and into the Gulf of Mexico and occasionally ventures into coastal waters. These few records are helpful in adding to the current knowledge of this species' range.

SEDAR77-RD03
Title: Use of marine protected areas and exclusive economic zones in the subtropical western North Atlantic Ocean by large highly mobile sharks.
Synopsis: To fill in knowledge gaps on the effectiveness of marine protected areas (MPA) to large shark species, bull, great hammerhead, and tiger sharks were satellite tagged to examine core habitat use areas in relation to established MPAs in the western North Atlantic Ocean. Eighteen great hammerhead sharks were tagged with smart position and temperature transmitting (SPOT) tags from 2010-2013 and tracked for 2 to 154 days with a total of 833 tracking days. The core habitat use area (85,061 km^2) for great hammerheads was primarily in the south Florida region encompassing both the Gulf of Mexico and South Atlantic Bight. Only 27% of the great hammerhead core use area was found to be protected from exploitation. The authors only presented a single representative track for great hammerheads, so it is not clear how many individuals moved to and from the Gulf of Mexico and South Atlantic Bight.

SEDAR77-RD04
Title: Overlap between highly suitable habitats and longline gear management areas reveals vulnerable and protected regions for highly migratory sharks
Synopsis: Maximum entropy habitat suitability models were developed for great hammerhead sharks *Sphyrna mokarran*, tiger sharks *Galeocerdo cuvier*, and bull sharks *Carcharhinus leucas* within the southeast region based on satellite tag (n = 96) and remotely sensed environmental data for comparison to longline gear management areas. Using data from 23 great hammerheads, habitat with the greatest probability of presence in the southeast region of the US EEZ from May-October was located in the Gulf of Mexico in the coastal waters from off Port Aransas, Texas down to the Mexican border, southwest of the Mississippi River Delta in Louisiana, southwest of Cape San Blas and around the Dry Tortugas and western Keys in Florida, and in the Atlantic off Florida around the Keys and throughout the continental shelf, but only offshore at the shelf edge off the northern part of the state. During November through April, habitat with the greatest probability of great hammerhead

presence in the southeast region of the US EEZ was off Florida in the Gulf of Mexico around the Keys, Dry Tortugas, and further west near this longitude. In the Atlantic, likelihood of greatest presence was found around the Keys and out along the shelf edge and slope up the coast from Florida through Georgia.

SEDAR77-RD05
Title: Regional-scale variability in the movement ecology of marine fishes revealed by an integrative acoustic tracking network
Synopsis: The goal of this study was to evaluate how an integrative acoustic telemetry tracking approach can provide multi-species movement data to improve our understanding of movement ecology and ecosystem processes, with a specific focus on the seasonal movements of predators off the west coast of Florida (WCF), USA. Three years of data (2016-2018) for 29 species (889 transmitters), ranging from large top predators to small consumers, from 21 acoustic telemetry arrays within the iTAG network in the eastern Gulf of Mexico were analyzed. Included in this synthesis were five great hammerheads (*Sphyrna mokarran*; 50 detection days). For analysis purposes, great hammerheads were grouped with tiger (*Galeocerdo cuvier*), lemon (*Negaprion brevirostris*), and sandbar (*Carcharhinus plumbeus*) sharks due to limited data on each species and similarities in life history, movement ecology, and shared taxonomy. Data indicated that great hammerheads exhibited northbound movements in spring and were southbound during the fall and were characterized as low-detection, long distance movers.

SEDAR77-RD08
Title: Seasonal movements and habitat use of juvenile smooth hammerhead sharks in the western North Atlantic Ocean and significance for management
Synopsis: This study used fin-mounted satellite tags to examine the movements and habitat use of juvenile smooth hammerheads, *Sphyrna zygaena*, a demographic segment particularly threatened by exploitation. Six sharks were tagged off the US mid-Atlantic region and tracked for 49–441 days (mean 187 ±136 days). Sharks consistently showed area-restricted movements within a summer core area in waters of the New York Bight and a winter core area off Cape Hatteras, North Carolina, with directed movements between those areas in autumn. There was high overlap of shark winter core area use and the Mid-Atlantic Shark Area (MASA) – a 7 month per year, bottom-longline fishery closure indicating that this area closure offers seasonal reduction in fishing pressure for this species. Generalized additive mixed models revealed that area-restricted movements of sharks in their summer and winter core areas coincided with high primary productivity, and elevated sea surface temperature. Consistency in use of summer and winter core areas suggests that the coastal waters of the New York Bight and Cape Hatteras, North Carolina could be considered for Essential Fish Habitat designation for this species. This study reveals the first high-resolution movements and habitat use for smooth hammerheads in the western North Atlantic to inform management planning for this population.

SEDAR77-RD13
Title: Identification of young-of-the-year great hammerhead shark *Sphyrna mokarran* in northern

Florida and South Carolina
Synopsis: Two sharks, visually identified in the field as young-of-the-year (YOY) scalloped hammerhead *Sphyrna lewin*i, were identified as great hammerhead *Sphyrna mokarran* based on nuclear-encoded single nucleotide polymorphisms (SNP) and sequences of mtDNA. Individuals were captured and released in Bulls Bay, SC, and Saint Joseph Bay, FL, in 2013 and 2014, respectively. The observation of two *S. mokarran* neonates in nearshore habitat of South Carolina and the northern Gulf of Mexico coast of Florida indicates that *S. mokarran* may use nursery habitat further north and further inshore than known previously.

SEDAR77-RD16
Title: Philopatry and regional connectivity of the great hammerhead shark, *Sphyrna mokarran* in the U.S. and Bahamas
Synopsis: Biotelemetry techniques (acoustic and satellite), conventional tagging, laser-photogrammetry, and photo-identification were used to investigate the level of site fidelity/residency for great hammerheads to coastal areas in the Bahamas and U.S., and the extent of movements and connectivity of great hammerheads between the U.S. and Bahamas. Results revealed large-scale return migrations (3030 km), seasonal residency to local areas (some for 5 months), site fidelity (annual return to Bimini and Jupiter for many individuals) and numerous international movements. Regional movements were shown between Jupiter, Florida and off Grand Bahama, Andros, and South Carolina. Additionally movements occurred between Bimini and Jupiter, off Grand Bahama, Georgia and South Carolina, and the slope waters off Virginia.

SEDAR77-RD17
Title: Potential distribution of critically endangered hammerhead sharks and overlap with the small-scale fishing fleet in the southern Gulf of Mexico
Synopsis: Ecological niche models were used to estimate the distribution of bonnethead, great, and scalloped hammerhead sharks within the Gulf of Mexico and determine their overlap with the small-scale fishing fleet based out of the San Franciso de Campeche port. Areas with a relatively high environmental suitability for the bonnethead shark were located in coastal areas <30 m depth. Scalloped hammerhead areas with a relatively high environmental suitability were located on the continental shelf from >10 m up to the 200 m isobath. Great hammerhead's potential distribution within the GOM was generally observed throughout the continental shelf with highest environmental suitability predicted in coastal and intermediate areas < 30 m depth.

SEDAR77-RD20
Title: Double tagging clarifies post-release fate of great hammerheads
Synopsis: This study used a combination of tags to examine horizontal movements and verify post-release fate of great hammerheads in the northern Gulf of Mexico. Three individuals (one male and two females) were equipped with both fin-mounted smart position and temperature transmitting (SPOT) tags and survivorship pop-off archival tags (sPAT). Tagged sharks measured 187 (F), 203 (M), and 250 (M) cm total length. A single fin-mounted SPOT tag, attached to the smallest of the three sharks, reported position estimates over an 81-day period and moved a straight-line distance of approximately 400 km; however, the other two fin-mounted SPOT tags failed to generate position estimates. All three sPAT tags indicated post-release survival. Final positions of the sPAT tags from the two largest sharks suggested restricted horizontal movements (< 35 km).

SEDAR77-RD21

Title: Defining sex-specific habitat suitability for a northern Gulf of Mexico shark assemblage
Synopsis: The authors used survey catch data and a suite of environmental variables to predict habitat suitability for small coastal, large coastal, and shelf associated sharks. Scalloped hammerheads were the most abundant shelf-associated species; males were encountered across a wider range of sizes than females. Males and females were encountered broadly across the continental shelf. Females were much less common than males (0.36:1. Female scalloped hammerhead abundance was influenced by distance from shore, depth, and bottom salinity, with little seasonal variation. Female scalloped hammerheads were encountered 75–85 km offshore, at depths between 50 and 100 m. Suitable habitat for female scalloped hammerheads was restricted to a small core area directly south of Mobile Bay, Alabama. Male scalloped hammerhead abundance was influenced by distance from shore, as well as bottom salinity and bottom velocity. Male scalloped hammerheads were encountered closer to shore (15–75 km offshore) relative to females, at depths between 25 and 100 m.

SEDAR77-RD22
Title: Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean
Synopsis: In this study, the distribution of Carolina hammerheads (*Sphyrna gilberti*) in waters of the United States off the east coast (U.S. Atlantic) and Gulf of Mexico (Gulf) was examined and their abundance relative to scalloped hammerheads (*S. lewini*) assessed by genetically identifying 1,231 individuals using diagnostic single nucleotide polymorphisms. Both species were found in the U.S. Atlantic, where 27 % of individuals were Carolina hammerheads, but only scalloped hammerheads were identified in the Gulf. In Bulls Bay, SC, a well-known hammerhead nursery, assessment of relative abundance from May to September showed scalloped hammerheads were more abundant May-June and Carolina hammerheads more abundant July-September. Results of this study suggest Carolina hammerheads have a spatially limited distribution in the western North Atlantic and highlight the importance of Bulls Bay as a nursery for the species. In addition, the results suggest Carolina hammerheads may comprise a non-trivial proportion of what is considered the U.S. Atlantic scalloped hammerhead stock and should be considered in future decisions regarding management of the hammerhead complex.

SEDAR77-RD23
Title: Distributions and movements of Atlantic shark species: A 52-year retrospective atlas of mark and recapture data
Synopsis: This document shows distribution and movement data obtained using mark and recapture data from NOAA Fisheries Cooperative Shark Tagging Program between 1962 and 2013 and includes data on three of the hammerhead species included in the Stock ID process for SEDAR 77. Tag and recapture data shows great hammerhead distribution throughout the shelf waters of the Gulf of Mexico and US Atlantic up off New Jersey. Winter distribution is constricted to shelf waters off Florida, primarily at the shelf edge, in the Atlantic and Gulf. Mark-recapture data for the great hammerhead shows no exchange between the Gulf and Atlantic, but does show exchange between the US and Mexican Gulf waters. Scalloped hammerhead distribution based on tag and recapture data also occurs throughout the shelf waters of the Gulf and US Atlantic up off New York. Winter distribution for scalloped hammerheads is primarily located along the shelf edge and only extends north off North Carolina in the US Atlantic. Mark-recapture data for scalloped hammerheads shows exchange between the US and Mexican Gulf and between the Gulf and the Atlantic. Smooth hammerhead distribution based on tag and recapture data only occurs in the US Atlantic excluding

the Gulf of Mexico. In the Atlantic, distribution extend from off Florida to southern New England with the majority of records north of North Carolina, similar to what is seen in the summer distribution. Fall smooth hammerhead distribution was only recorded from North Carolina and north. Winter had very few records (n=6) only located off Florida's east coast and spring only had records off North Carolina and south. Mark-recapture data only showed movements along the US east coast ranging from New Jersey to Florida.

SEDAR77-RD24
Title: First identification of probable nursery habitat for critically endangered great hammerhead *Sphyrna mokarran* on the Atlantic Coast of the United States
Synopsis: Identification of potential nursery habitat within Biscayne Bay near Miami, Florida. Small juveniles <100 cm total length (TL) were captured at this site between June 2018 and January 2020 TL. Species identification was confirmed through genetic analysis.

SEDAR77-RD25
Title: Characterization of a scalloped hammerhead (*Sphyrna lewini*) nursery habitat in portions of the Atlantic Intracoastal Waterway
Synopsis: The Tolomato River in northeastern Florida provides important nursery habitat for scalloped hammerhead sharks. Fishery-independent survey, mark-recapture, and acoustic tracking data show that this area within the Intracoastal Waterway hosts high consistent numbers of young-of-the-year scalloped hammerheads annually (2009-2019) for extended periods of time (May through August).

2.3.6 **Great Hammerhead**

Terms of Reference: The goal of the Stock ID workshop was to review great hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution and movements in the Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of great hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of great hammerheads in relation to distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements Workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the

working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4'N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that great hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico and should be assessed as a single stock. Although conventional tag data (SEDAR77-RD23) did not show exchange between the Atlantic and Gulf, satellite telemetry data did verify the movement of individuals across the proposed boundary between regions (SEDAR77-SID01, SEDAR77-SID07).

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, the movement/migration data available for great hammerheads from the Gulf of Mexico and Atlantic Ocean is limited and the Spatial-Movement Workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: Great hammerheads are the largest of the hammerhead species and are widely distributed in warm temperate and tropical waters (Compagno 1984). They are considered highly migratory with the ability to move long distances over short periods of time (i.e. over 1,200 km in a 30-day period; Hammerschlag et al. 2011). Conventional tagging data shows that both sexes of this species are present in continental shelf waters throughout the Gulf of Mexico and U.S. Atlantic Ocean to up off New Jersey with winter distribution constricted to shelf and slope waters off Florida (SEDAR77-RD23, Figures 1 and 2). This distribution range is supported by additional working and reference documents reviewed during the Stock ID process for SEDAR 77. In 52-years of NOAA Fisheries Cooperative Shark Tagging Program, there were five recaptures showing exchange between the U.S. and Mexican Gulf of Mexico, but not between the Gulf of Mexico and Atlantic Ocean (SEDAR77-RD23; Figure 3). Similarly, though data are limited, satellite and acoustic telemetry studies reviewed also revealed localized movements within the Gulf of Mexico and the U.S. Atlantic Ocean. However, animals tagged in the Florida Keys have been shown to use either body of water and exchange between the Gulf of Mexico and Atlantic Ocean is evident (SEDAR77-SID01, SEDAR77-SID07, Figures 4, 5). These data are preliminary and tagging studies are ongoing.

Recommendation for Stock ID:
Great hammerhead (*Sphyrna mokarran*): Great hammerheads in the Gulf of Mexico and Atlantic

Ocean are a single biological stock and should be assessed as one management stock.

2.3.7 **Smooth Hammerhead**

Terms of Reference: The goal of the Stock ID workshop was to review smooth hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of smooth hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of smooth hammerheads in relation to distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4'N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that smooth hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico and should be assessed as a single management stock. Although conventional tag data (SEDAR77-RD23) did not show any records in the Gulf of Mexico or any exchange between the Atlantic and Gulf, there are a few accounts of smooth hammerheads observed in the Gulf (SEDAR77-RD02). Regardless, they are a wide-ranging species with the ability to move long distances (> 6,600 km; Santos and Coelho, 2018) and it is not inconceivable that this species could occasionally enter the Gulf.

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, spatial data, especially with respect to movements and migrations, available for smooth hammerhead from the Gulf of Mexico and Atlantic Ocean is scant at best and the Spatial-Movement workgroup recommends additional tagging (conventional, acoustic, and satellite) studies

to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: The smooth hammerhead is a circumglobal, semi-pelagic species found in amphitemperate and tropical waters (Compagno, 1984). Conventional tagging data shows that both sexes of this species are present off the east coast of the U.S. in the Atlantic Ocean from off Florida to southern New England (SEDAR77-RD23, Figure 6). Seasonal distribution during the summer is similar to the overall distribution, but records were only present off North Carolina and further north in the fall, off North Carolina and further south in the spring, and there were limited records (n=6) during the winter located off Florida (SEDAR77-RD23, Figure 7). In 52-years of the NOAA Fisheries Cooperative Shark Tagging Program, there were seven recaptures and no exchange between the Gulf of Mexico and Atlantic Ocean (SEDAR77-RD23, Figure 8). To date, there is only a single satellite telemetry study where six tagged juvenile smooth hammerheads showed area restricted movements in the U.S. mid-Atlantic region; no individuals entered the Gulf of Mexico (SEDAR77-RD08, Figure 9). Given the known range of the smooth hammerhead extends south to the Caribbean Sea and beyond, there is no barrier keeping this species from entering the Gulf of Mexico (SEDAR77-RD02). Until recently, there were no reliable records for the Gulf of Mexico. A single individual smooth hammerhead was found dead in the shallow waters off the northeast Gulf of Mexico, and a dozen or so other observations from the NOAA NMFS Observer Program highlights their presence in this region (SEDAR77-RD08). Their occurrence in the Gulf of Mexico is not inconceivable as they are a wide-ranging species with the ability to move long distances (> 6,600 km; Santos and Coelho, 2018).

Recommendation for Stock ID:
Smooth hammerhead (*Sphyrna zygaena*): Smooth hammerheads are likely one biological stock in the Gulf of Mexico and Atlantic Ocean and should be assessed as one management stock.

2.3.8 **Scalloped Hammerhead**

Terms of Reference: The goal of the Stock ID workshop was to review scalloped hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the South Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of scalloped hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of scalloped hammerheads in relation to

distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4'N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that scalloped hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico. Conventional tag data (SEDAR77-RD23) and satellite telemetry data (SEDAR77-SID01, SEDAR77-SID07) do show exchange between the Atlantic and Gulf for the scalloped hammerhead. However, the Carolina hammerhead overlaps in distribution in the Atlantic, is not found in the Gulf, and is externally indistinguishable from the scalloped hammerhead (SEDAR77-RD22). For these reasons, the Spatial-Movement workgroup agreed on two options:

1) Scalloped hammerheads should be assessed as two management stocks,
    a. Atlantic Ocean – scalloped and Carolina hammerhead complex
    b. Gulf of Mexico – scalloped hammerhead
2) If scalloped hammerhead data cannot support a separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess scalloped hammerheads as a single management stock with Carolina hammerheads in the Atlantic and Gulf combined

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, the movement/migration data available for scalloped hammerhead from the Gulf of Mexico and Atlantic Ocean is limited and the Spatial-Movement workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: Scalloped hammerheads are a large, semi-coastal species with a

circumtropical range (Compagno 1984). Conventional tagging data shows that both sexes of this species are present throughout the Gulf of Mexico and U.S. Atlantic Ocean up off New York (SEDAR77-RD23, Figure 10). Seasonal distribution is similar throughout the year except during winter when the distribution is primarily located along the shelf edge and only extends north in the Atlantic to off North Carolina (SEDAR77-RD23, Figures 11). This distribution range is supported by additional working and reference documents reviewed during the Stock ID process for SEDAR 77. In 52-years of NOAA Fisheries Cooperative Shark Tagging Program, there were 62 recaptures showing exchange between the Gulf of Mexico and Atlantic Ocean and between the U.S. and Mexican Gulf of Mexico (SEDAR77-RD23, Figure 12). Similarly, though data are limited, satellite telemetry data show that there is exchange between the Gulf of Mexico and Atlantic Ocean and animals tagged in the Florida Keys have been shown to use either body of water (SEDAR77-SID01, SEDAR-SID07, Figures 13, 14).

Recommendation for Stock ID:

Scalloped hammerhead (*Sphyrna lewini*): Scalloped hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico, but the Carolina hammerhead overlaps in distribution in the Atlantic, is not found in the Gulf, and is externally indistinguishable from the scalloped hammerhead, therefore:

Scalloped hammerheads should be assessed as two management stocks,

1. Atlantic Ocean – scalloped and Carolina hammerhead complex
2. Gulf of Mexico – scalloped hammerhead

Secondary recommendation: If scalloped hammerhead data cannot support separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess scalloped hammerheads as a single management stock (scalloped and Carolina hammerhead complex) in the Atlantic and Gulf combined

2.3.9 **Carolina Hammerhead**

Terms of Reference: The goal of the Stock ID workshop was to review Carolina hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the South Atlantic, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of Carolina hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of Carolina hammerheads in relation to distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4'N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that Carolina hammerheads comprise a single biological stock in the Atlantic Ocean. There are no movement data available for this species and limited distribution data has it ranging from North Carolina to Florida (SEDAR77-RD22) However, the Carolina hammerhead overlaps in distribution with the scalloped hammerhead in the Atlantic and is externally indistinguishable from the scalloped hammerhead (SEDAR77-RD22). For these reasons, the Spatial-Movement workgroup agreed on two options:

1) Carolina hammerheads should be assessed as a single management stock in the Atlantic (scalloped and Carolina hammerhead complex)
2) If scalloped hammerhead data cannot support separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess Carolina hammerheads as a single management stock in the Atlantic and Gulf (scalloped and Carolina hammerhead complex)

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, the movement/migration data available for Carolina hammerhead from the Atlantic Ocean is non-existent and the Spatial-Movement workgroup recommends tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: There is a paucity of data for Carolina hammerheads. Limited available data suggest this species has a spatially limited distribution in the Atlantic Ocean, primarily occurring from North Carolina to Florida (SEDAR77-RD22, Figure 15). As this is a cryptic species and indistinguishable from scalloped hammerheads using external morphology, it is difficult to obtain verifiable records of this species. Since field identification is nearly impossible, no tagging studies have been performed to date. A recent genetics study of Carolina and scalloped

hammerheads revealed that Carolina hammerheads accounted for 27% of the population in the Atlantic Ocean and only scalloped hammerheads were observed in the Gulf of Mexico (SEDAR77-RD22).

Recommendation for Stock ID:

Carolina hammerhead (*Sphyrna gilberti*): Carolina hammerheads comprise a single biological stock in the Atlantic Ocean, but the Carolina hammerhead overlaps in distribution with the scalloped hammerhead in the Atlantic and is externally indistinguishable from the scalloped hammerhead, therefore:

Carolina hammerheads should be assessed as a single management stock in the Atlantic (scalloped and Carolina hammerhead complex)

Secondary recommendation: If scalloped hammerhead data cannot support separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess Carolina hammerheads as a single management stock (scalloped and Carolina hammerhead complex) in the Atlantic and Gulf combined

2.3.10 **Catches Working Group**

BACKGROUND

The spatial distribution of commercial landings and recreational catches was investigated as a potential surrogate for movement to help identify stocks of the three hammerhead shark species.

2.3.10.1 COMMERCIAL LANDINGS

Commercial landings of scalloped, great, and smooth hammerheads in 1991-2020 were extracted from the FINS database, which includes landings from the Atlantic Coastal Cooperative Statistics Program (ACCSP) and the Gulf Fisheries Information Network (GulfFIN) for the Atlantic and Gulf of Mexico (GOM) regions, respectively. Commercial landings aggregated over the entire period by state of landing showed that scalloped hammerheads were mostly landed on both coasts of Florida, followed by North Carolina on the Atlantic coast and Louisiana in the GOM (Figure 16 top). Great hammerheads were mostly caught on Florida's GOM coast and North Carolina (Figure 16 middle), whereas smooth hammerheads were exclusively landed in the Atlantic coast, in New York, Virginia, and North Carolina (Figure 16 bottom).

Since the state where sharks are landed may differ from the state where they are caught we examined the location of commercial catches as reported in the FINS database for the same period. Except for catches off Louisiana, most of the catches of scalloped hammerheads in the GOM occurred on the west coast of Florida; those in the Atlantic were from the east coast of Florida, in the Florida Keys and off Central Florida, with the highest catches occurring in the mid-Atlantic region off North Carolina. Catches occurred during most months of the year, especially in the Atlantic region (Figure 17). Most catches of great hammerheads occurred off North Carolina and the Florida Keys, also during most months of the year (Figure 18). Catch location of smooth hammerheads was not reported in most cases; of those reported most were off North Carolina with some off Virginia, but

none in the GOM (Figure 19).

2.3.10.2 RECREATIONAL CATCHES

Almost all the recreational catches of the three hammerhead shark species during 1981-2020 came from the Marine Recreational Information Program (MRIP) and therefore only state of landing/catch is available. The MRIP estimates include Access Point Angler Intercept Survey (APAIS) and Fishing Effort Survey (FES) calibrations and the estimates reported here are the sum of type A (number of fish killed or kept seen by the interviewer) and type B1 (number of fish killed or kept reported to the interviewer by the angler) in number of animals.

Most scalloped hammerhead catches in 1981-2020 occurred in the Atlantic, from Florida's east coast to North Carolina, with lower catches in the GOM coming from Florida's west coast and Mississippi (Figure 20 top). Most catches occurred in waves 3 (May-June) and 4 (July-August) (Figure 20 middle) in most states where they were reported (Figure 20 bottom).

The vast majority of great hammerhead catches occurred in Florida, with about 20% more catches in the Atlantic than the GOM coast (Figure 21 top). Although higher catches also occurred in waves 3 and 4, unlike for scalloped hammerheads, great hammerheads were also caught significantly in waves 1 (January-February), 2 (March-April), and 5 (September-October) (Figure 21 middle). Interestingly, while great hammerheads on the east coast of Florida were caught mainly in waves 2, 3, and 4 (March through August), they were caught mostly in waves 1 (January-February) and 5 (Sept-October) on the west coast of Florida (Figure 21 bottom).

With the only exception of Florida's west coast (where there were estimated catches in 1982, 1987, and 1988), smooth hammerheads were caught exclusively in the Atlantic, from the east coast of Florida to Maryland (Figure 22 top). They were caught in waves 3 (May-June) and 6 (November-December), but also in waves 4 (July-August) and 5 (September-October) (Figure 22 middle). A large amount of smooth hammerheads were estimated to have been caught off Florida's east coast in wave 6 (November-December) (Figure 22 bottom).

2.3.10.3. DISCUSSION

Commercial landings and recreational catches were aggregated over the entire time periods available for this analysis. No patterns that could be used to discern different stocks of the three species were identified. One interesting result is the differential recreational catch of great hammerheads on the east coast of Florida during spring and summer compared to the west coast of Florida in winter and fall, which could potentially be attributed to movement of the same stock from one region to another. However, in the absence of detailed fishing effort information no conclusions can be drawn. A more in depth analysis than was possible for this stock ID workshop could be undertaken in the future as a research topic to help differentiate between stocks using catch and effort data and considering the effect of mis-identification, especially for recreational fisheries.

2.3.11 **Literature Cited**

Compagno, L.J.V. 1984. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2: Carcharhiniformes. FAO Fish. Synop. 4 (125): 251–655.

Hammerschlag, N., Gallagher, A.J., Lazarre, D.M., Slonim, C. 2011. Range extension of the endangered great hammerhead shark *Sphyrna mokarran* in the northwest Atlantic: preliminary data and significance for conservation. Endangered Species Research 13: 111-116. doi: 10.3354/esr00332.

Santos C.C., Coelho, R. 2018. Migrations and habitat use of the smooth hammerhead shark (*Sphyrna zygaena*) in the Atlantic Ocean. PLoS ONE 13(6): e0198664. doi: 10.1371/ journal.pone.0198664.

2.3.12 **Figures**

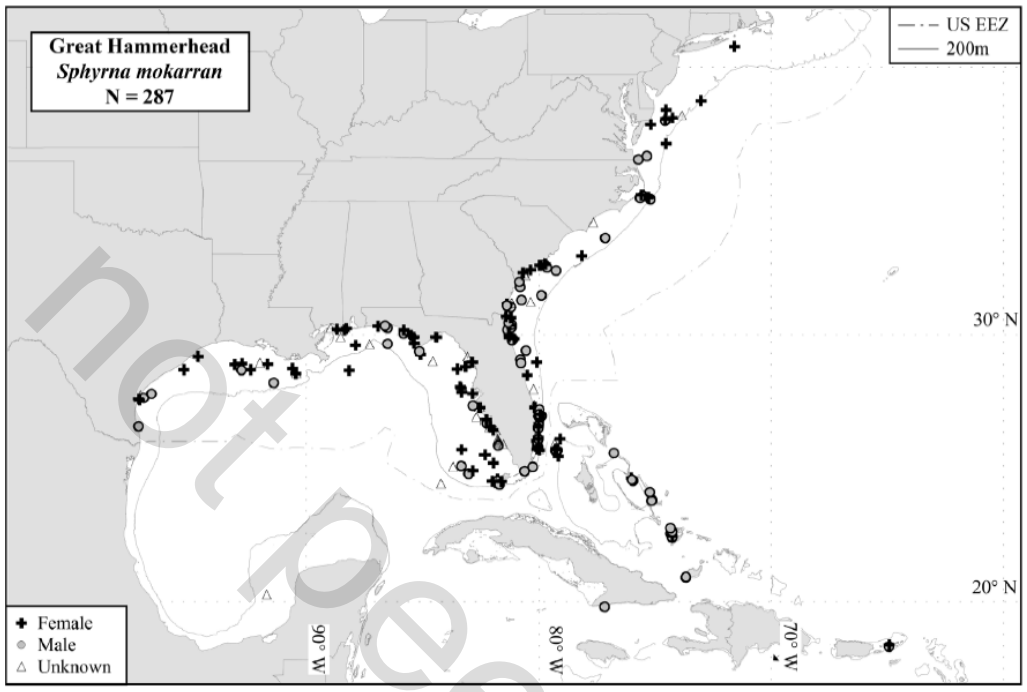


Figure 1. Cooperative Shark Tagging Program distribution of tag and recapture locations for great hammerheads from 1962-2013 (SEDAR77-RD23).

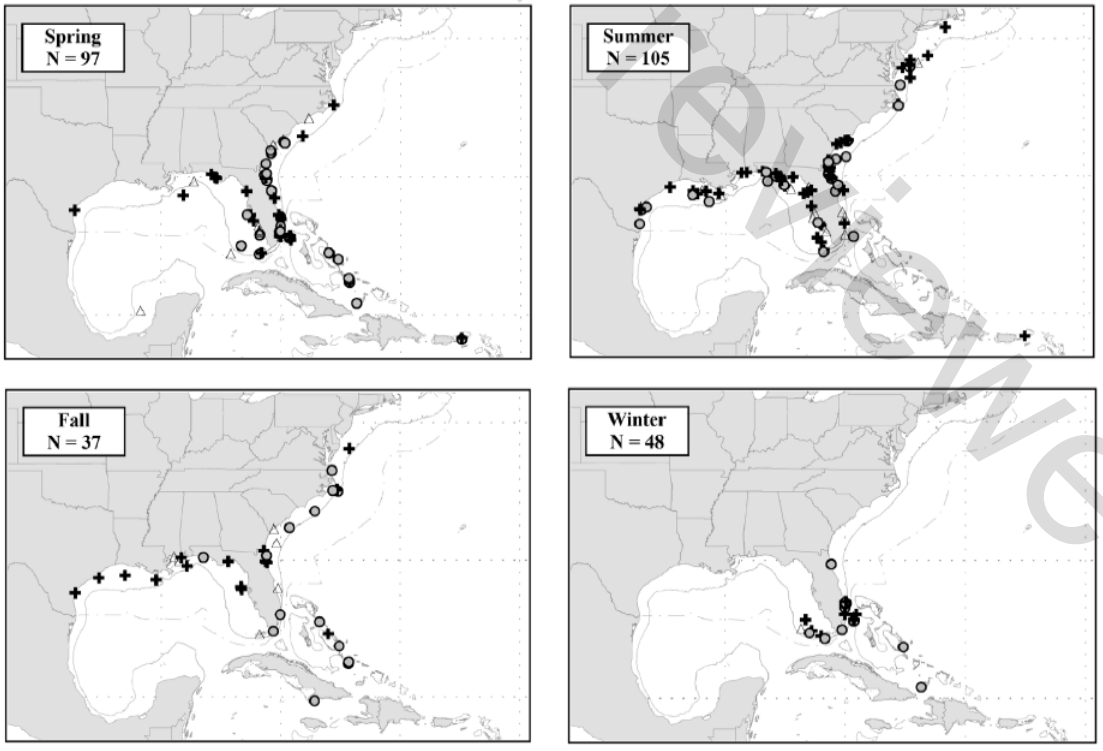


Figure 2. Cooperative Shark Tagging Program seasonal distribution of tag and recapture data for the great hammerhead from 1962-2013 (SEDAR77-RD23).

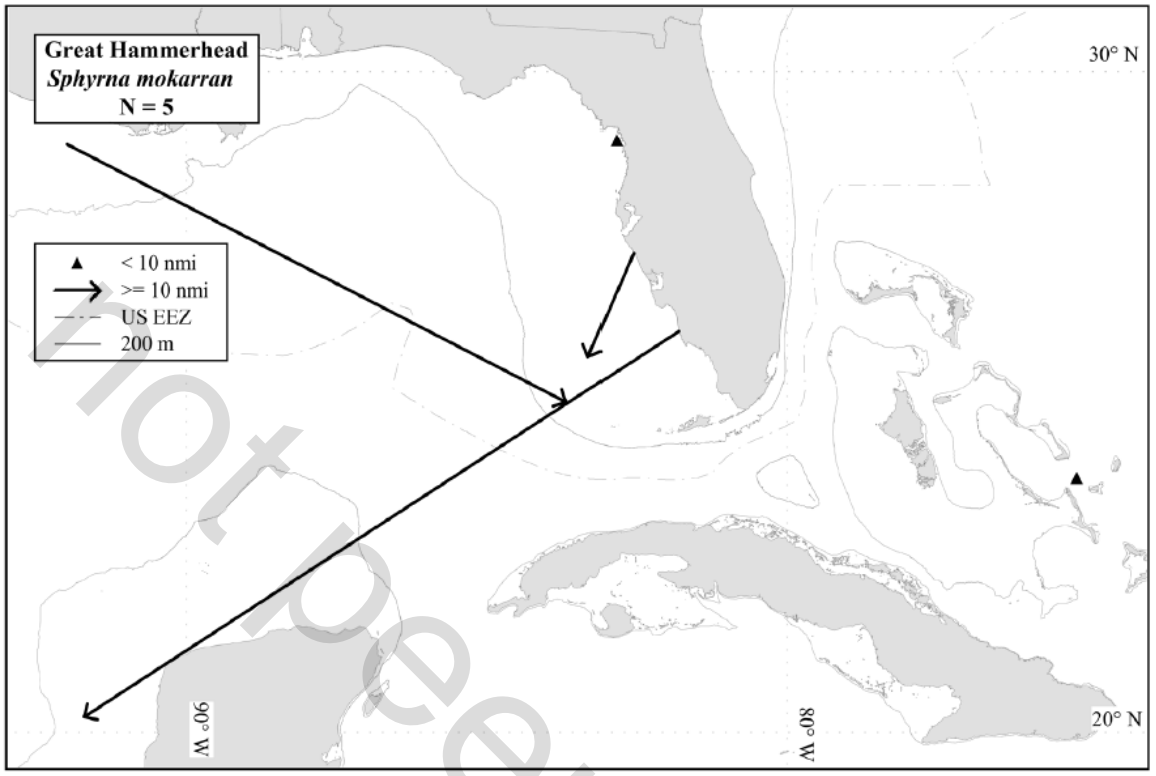


Figure 3. Cooperative Shark Tagging Program mark-recapture data for great hammerhead from 1962-2013. Data indicates exchange between the US and Mexican Gulf of Mexico (SEDAR77-RD23).

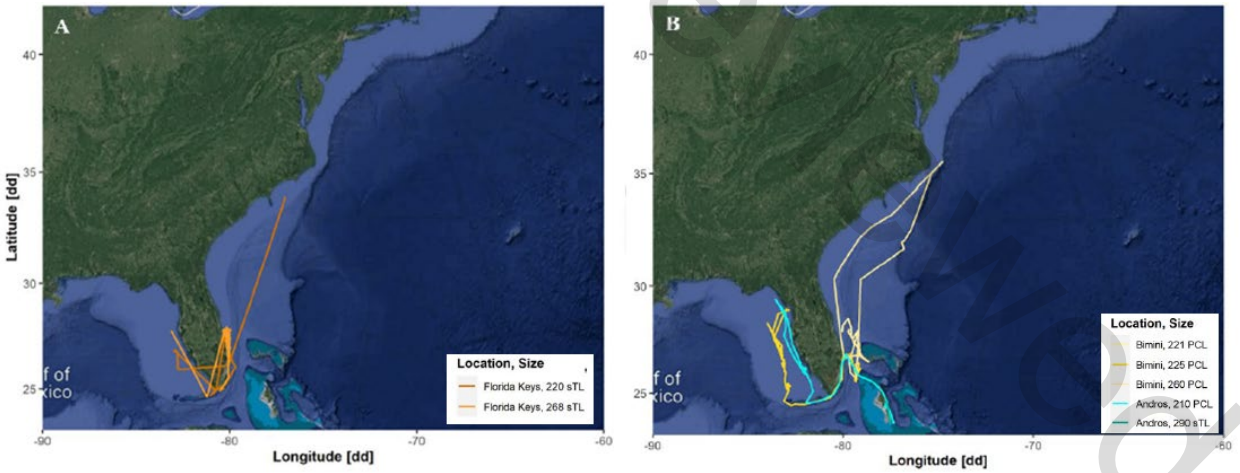


Figure 4. Regional movements of sexually immature female (A) and mature female (B) satellite tagged great hammerheads 2019-2021 (SEDAR77-SID01). Tracks indicate exchange between the Gulf of Mexico and Atlantic Ocean.

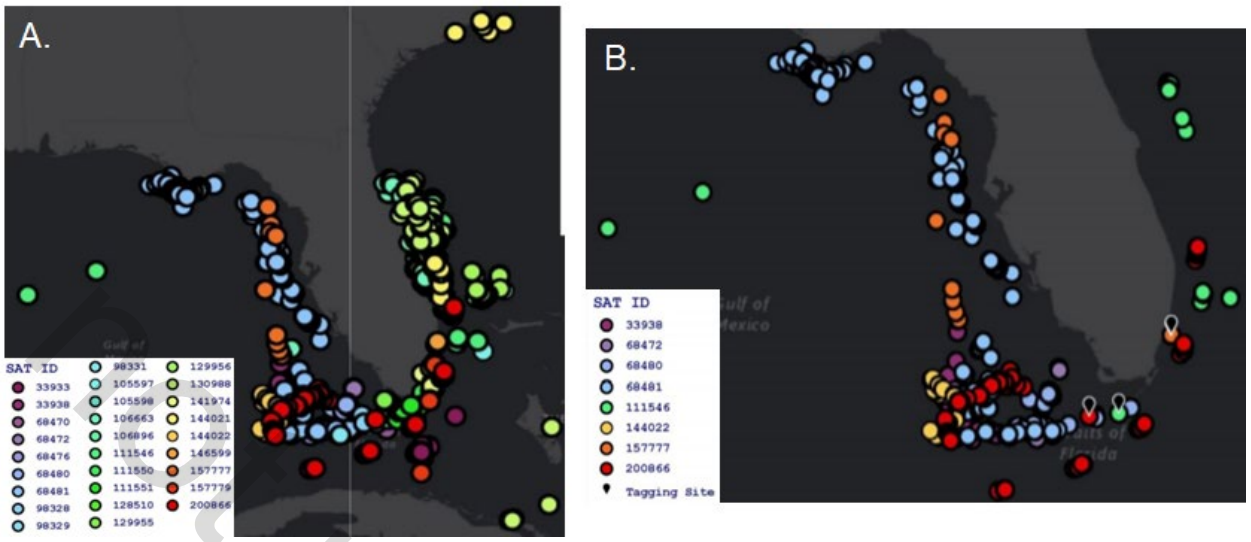


Figure 5. (A) Raw positions received from ARGOS for satellite tagged great hammerheads (n=28) and (B) the same plot restricted to animals that showed exchange between the Gulf of Mexico and Atlantic Ocean (n=8; SEDAR77-SID07).

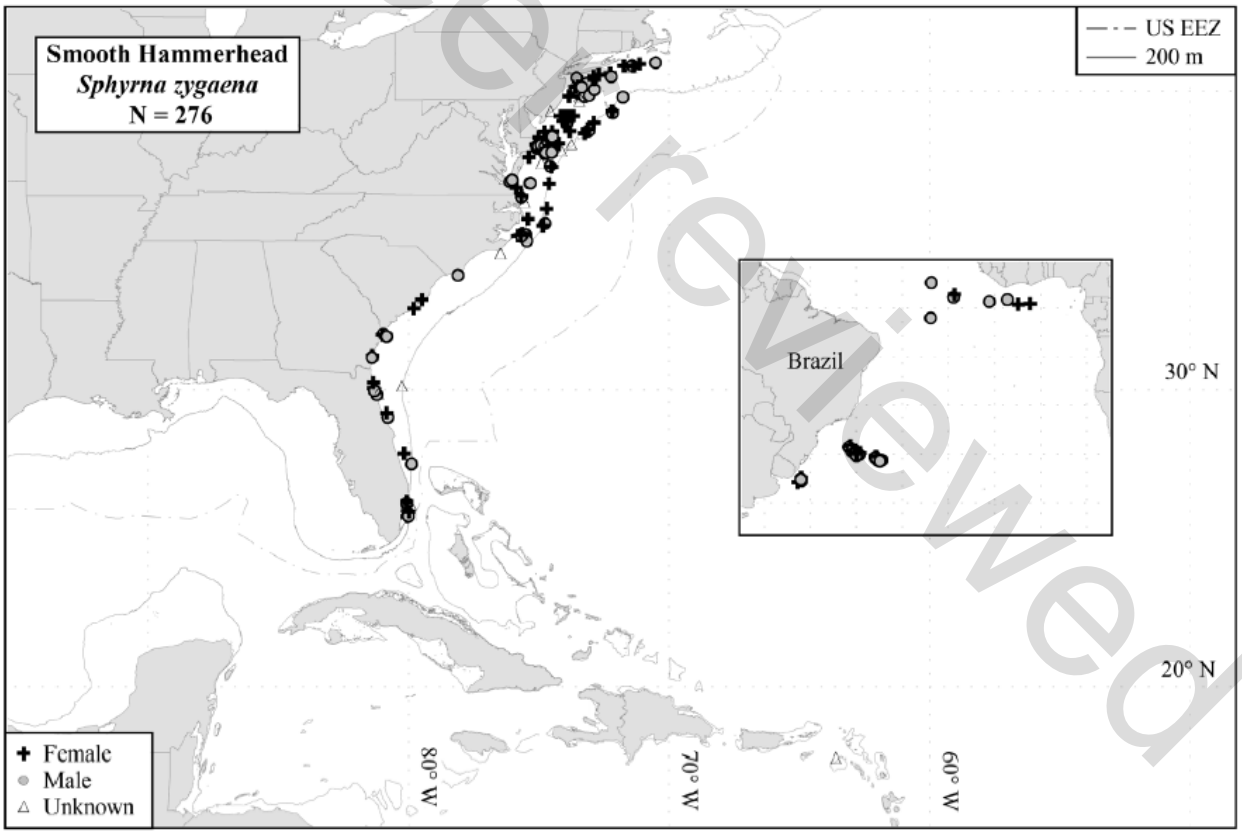


Figure 6. Cooperative Shark Tagging Program distribution of tag and recapture locations for smooth hammerheads from 1962-2013 (SEDAR77-RD23).

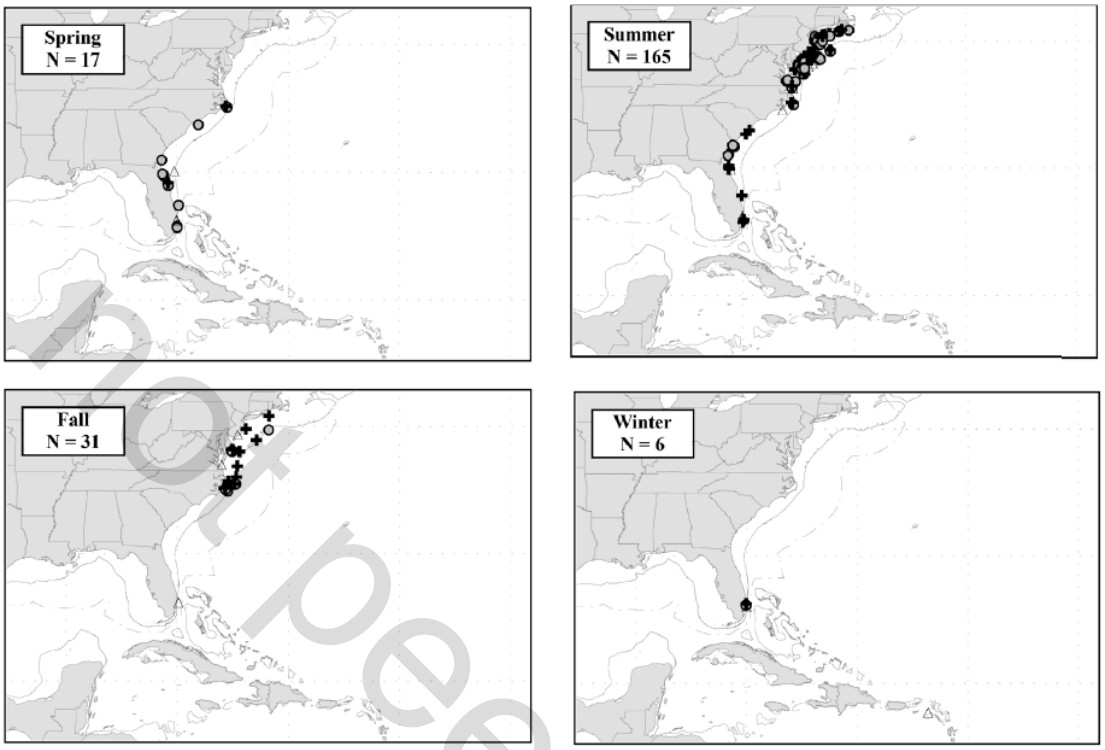


Figure 7. Cooperative Shark Tagging Program seasonal distribution of tag and recapture data for the smooth hammerhead from 1962-2013 (SEDAR77-RD23).

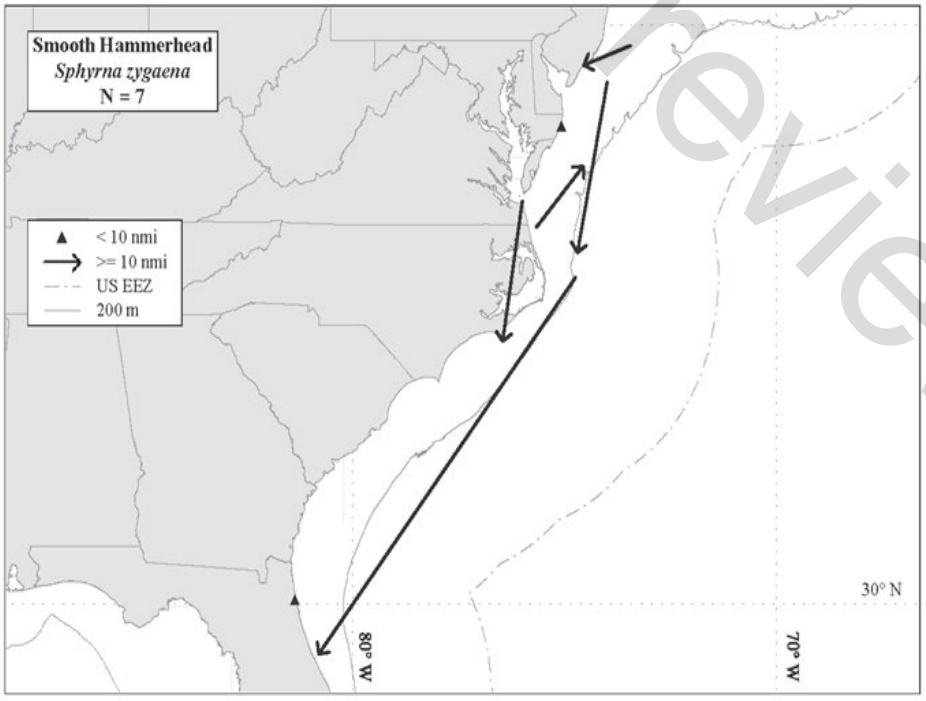


Figure 8. Cooperative Shark Tagging Program mark-recapture data for smooth hammerhead from 1962-2013 (SEDAR77-RD23). No exchange is apparent between the Gulf of Mexico and the Atlantic Ocean.

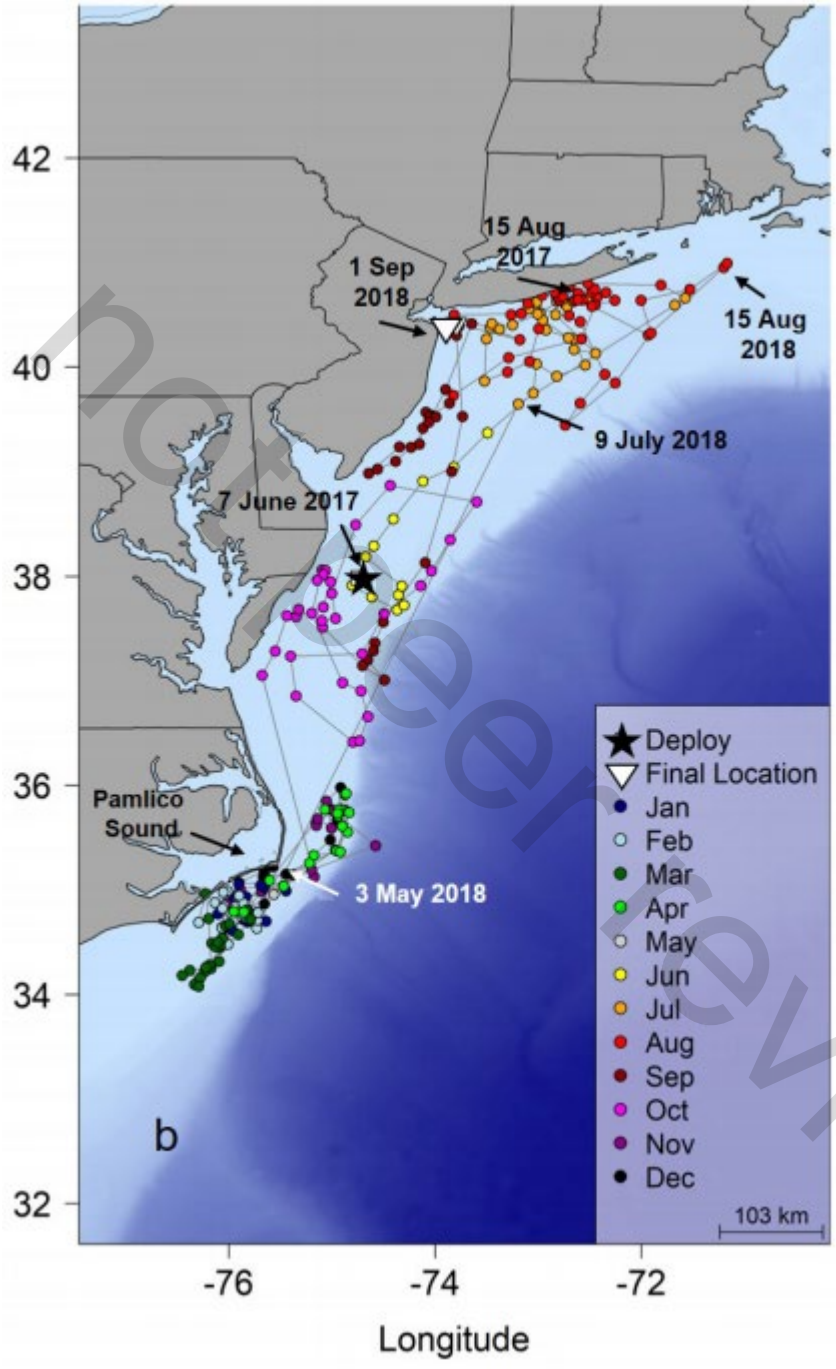


Figure 9. Satellite tag tracks of a juvenile smooth hammerhead from 2017-2018. No exchange between the Gulf of Mexico and Atlantic Ocean (SEDAR77-RD08).

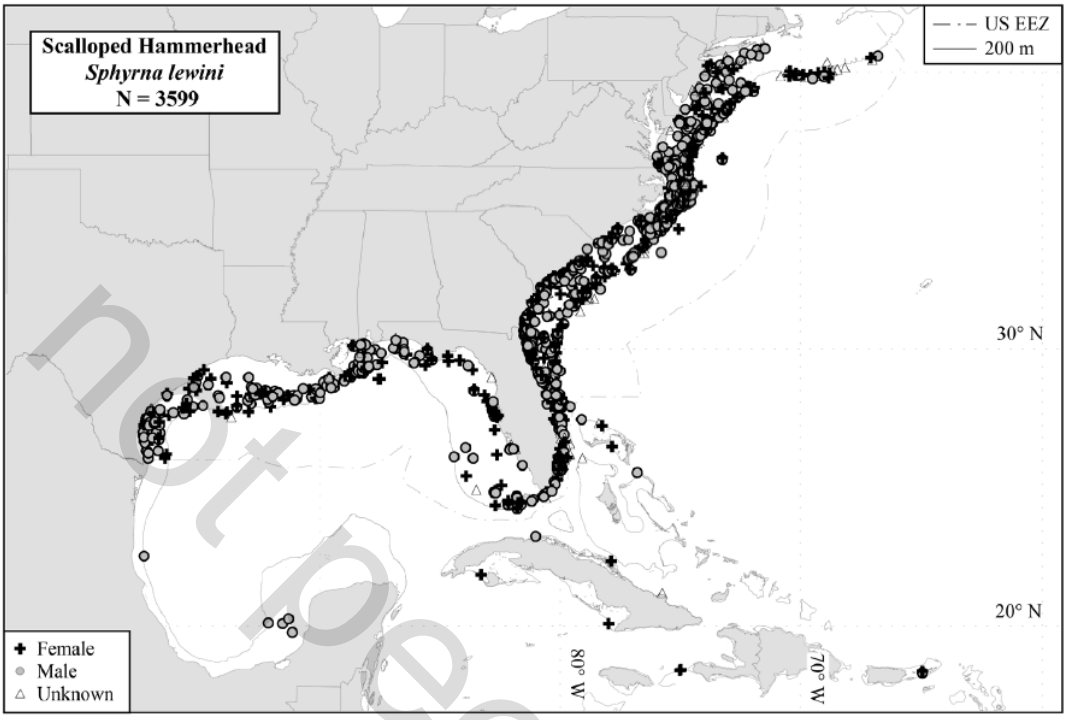


Figure 10. Cooperative Shark Tagging Program distribution of tag and recapture locations for scalloped hammerheads from 1962-2013 (SEDAR77-RD23).

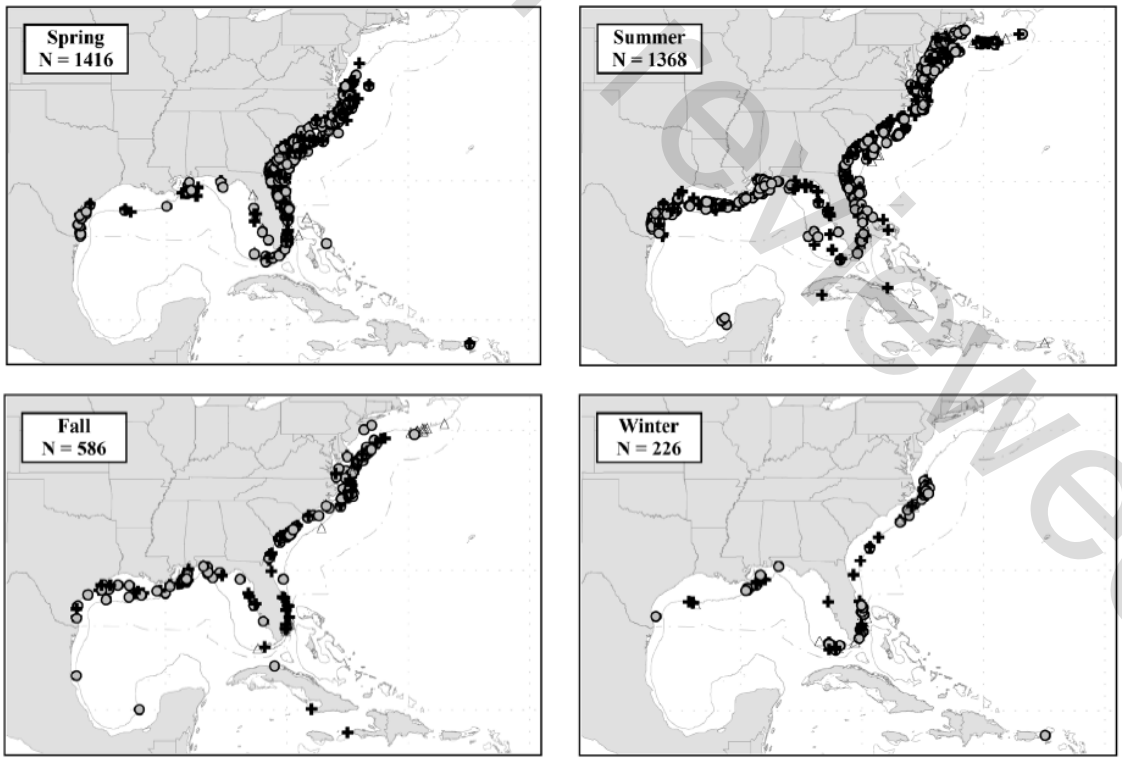


Figure 11. Cooperative Shark Tagging Program seasonal distribution of tag and recapture data for the scalloped hammerhead from 1962-2013 (SEDAR77-RD23).

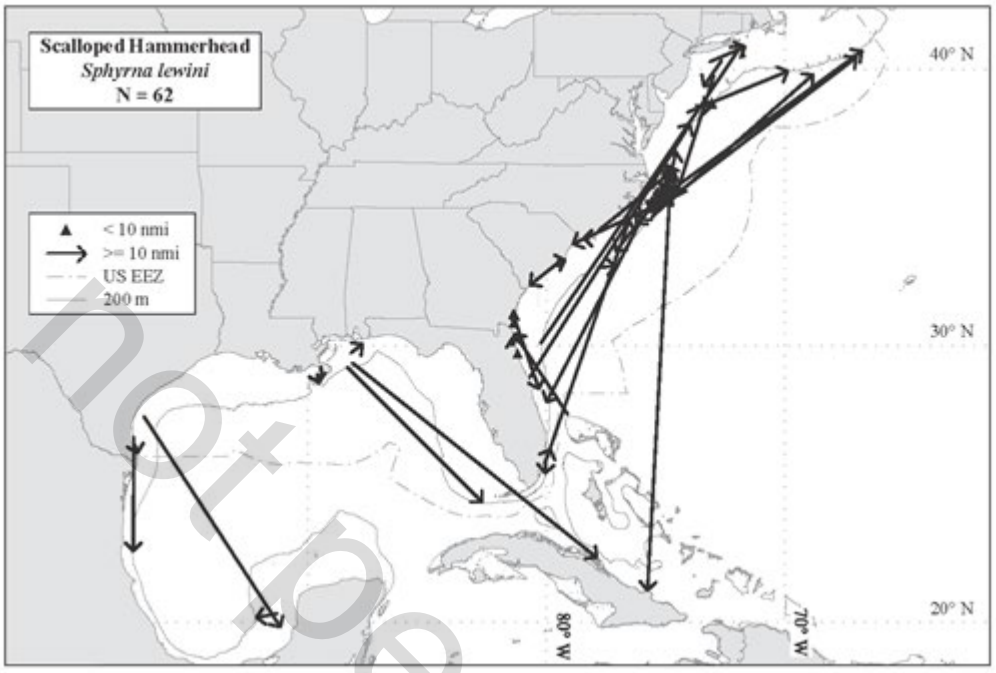


Figure 12. Cooperative Shark Tagging Program mark-recapture data for scalloped hammerhead from 1962-2013 (SEDAR77-RD23). Exchange is apparent between the Gulf of Mexico and the Atlantic Ocean and between the US and Mexican Gulf of Mexico.

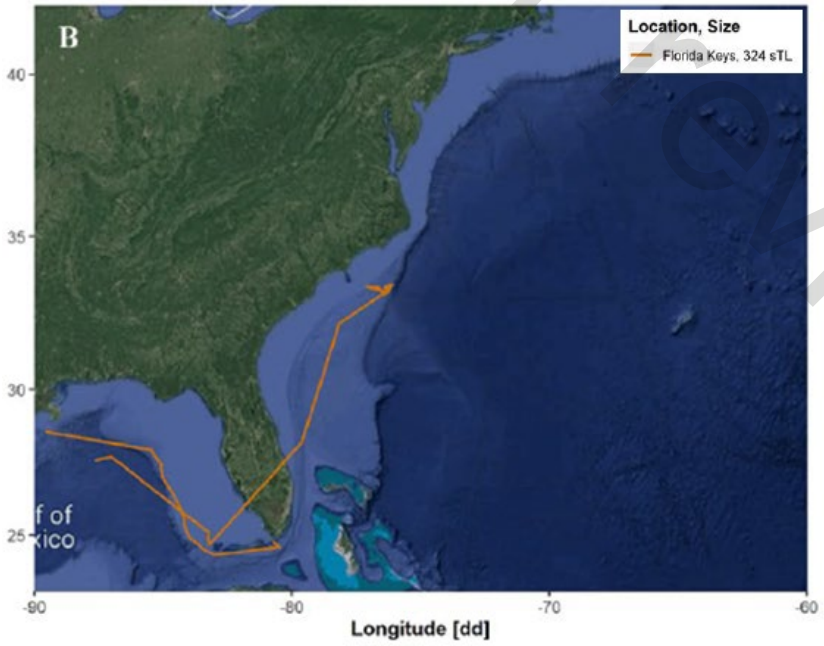


Figure 13. Regional movement track of a satellite tagged mature male scalloped hammerhead 2019-2021 (SEDAR77-SID01). The track indicates exchange between the Gulf of Mexico and Atlantic Ocean.

Figure 14. Raw positions received from ARGOS for satellite tagged scalloped hammerheads (n=5). Positions indicate exchange between the Gulf of Mexico and Atlantic Ocean (SEDAR77-SID07).

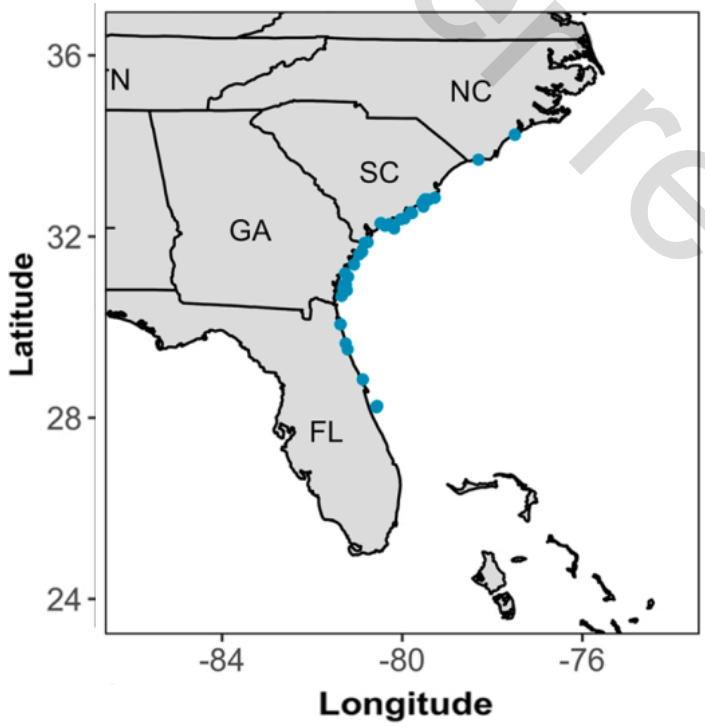


Figure 15. Sampling locations of Carolina hammerheads 2010-2019 (SEDAR77-RD22). No exchange between the Gulf of Mexico and Atlantic Ocean.

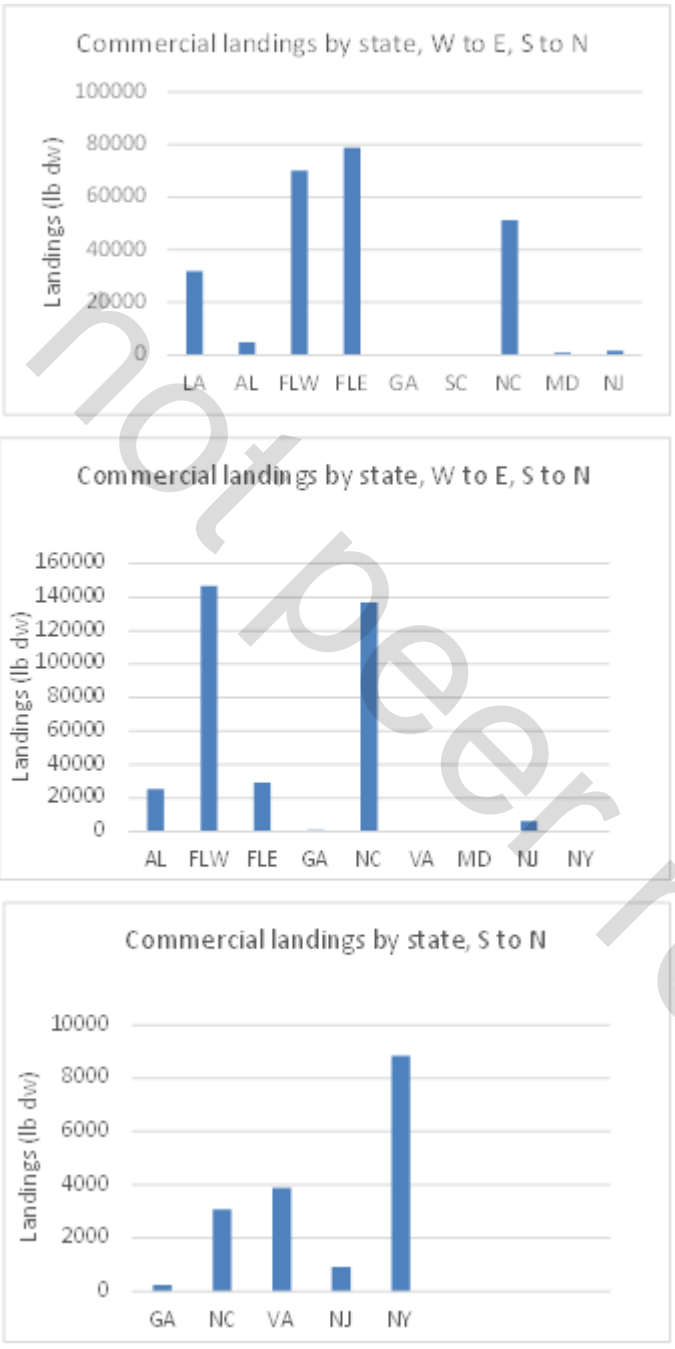


Figure 16. Total landed pounds (dressed weight) of scalloped (top), great (middle), and smooth (bottom) hammerhead sharks for 1991-2020 by state of landing reported in the FINS database. States are listed from west to east in the Gulf of Mexico and from south to north in the Atlantic. Note the different scales on the vertical axis.

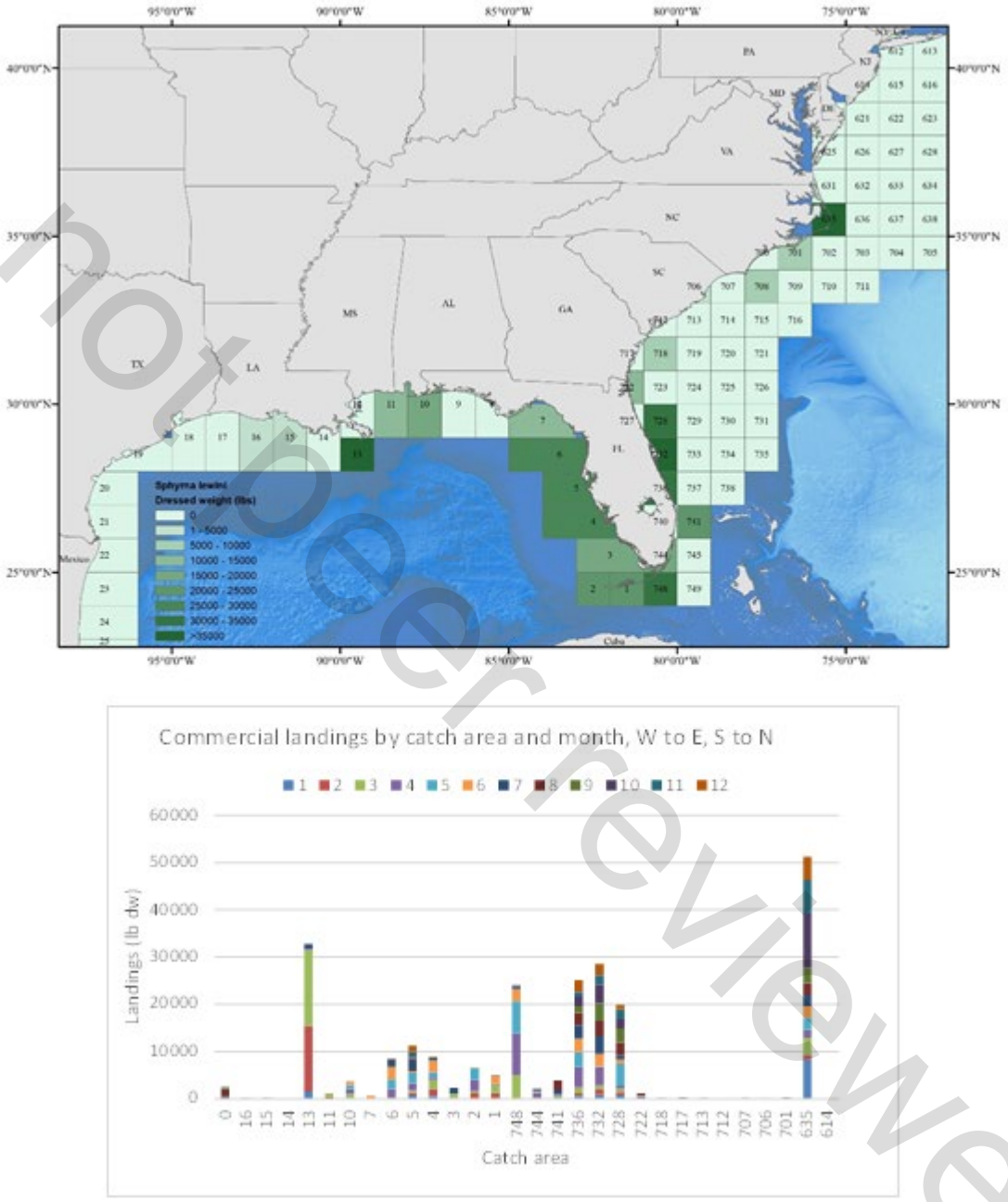


Figure 17. Total landed pounds (dressed weight) of scalloped hammerhead sharks for 1991-2020 by catch area reported in the FINS database. The bottom panel shows the catch areas from west to east in the Gulf of Mexico and from south to north in the Atlantic.

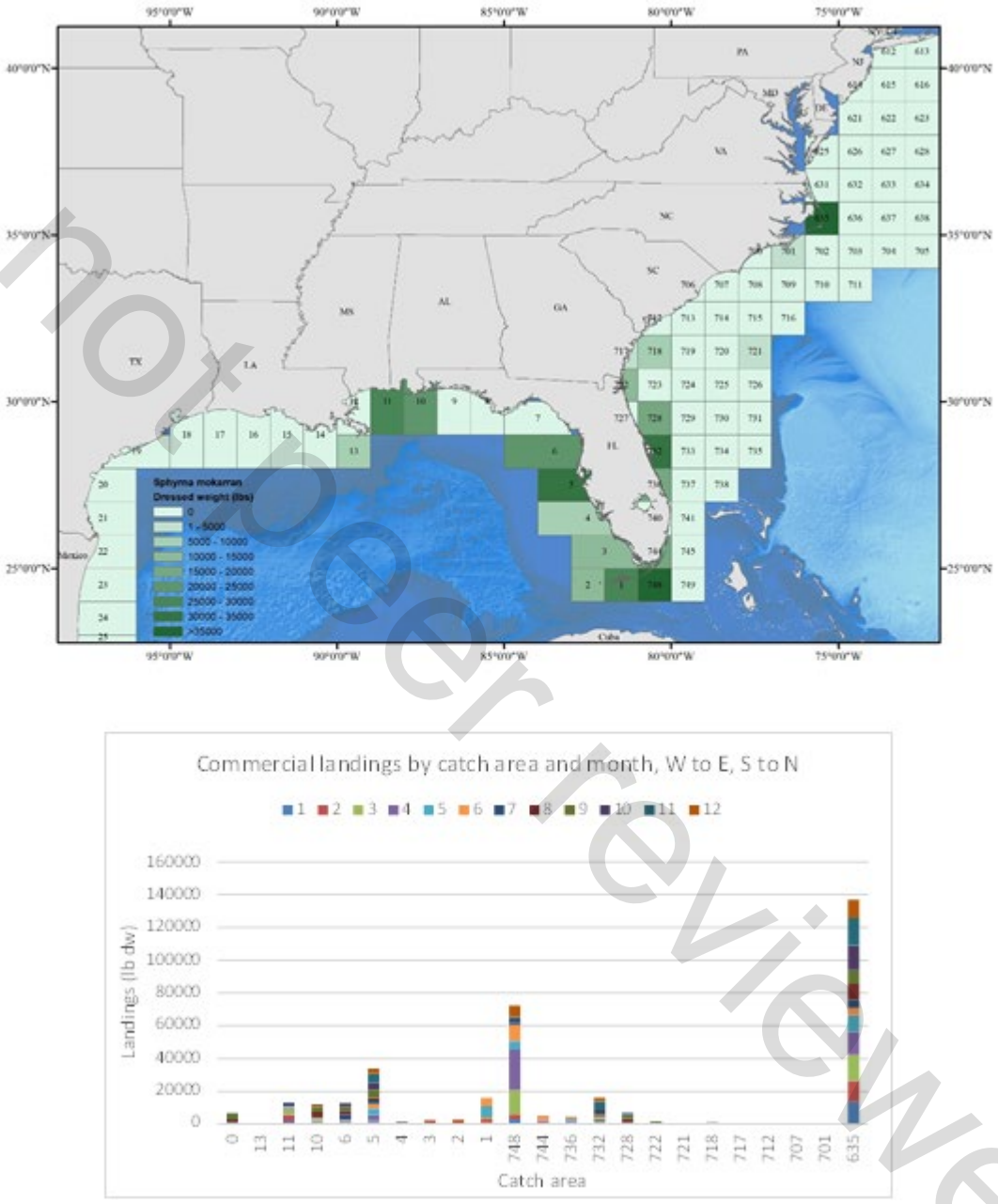
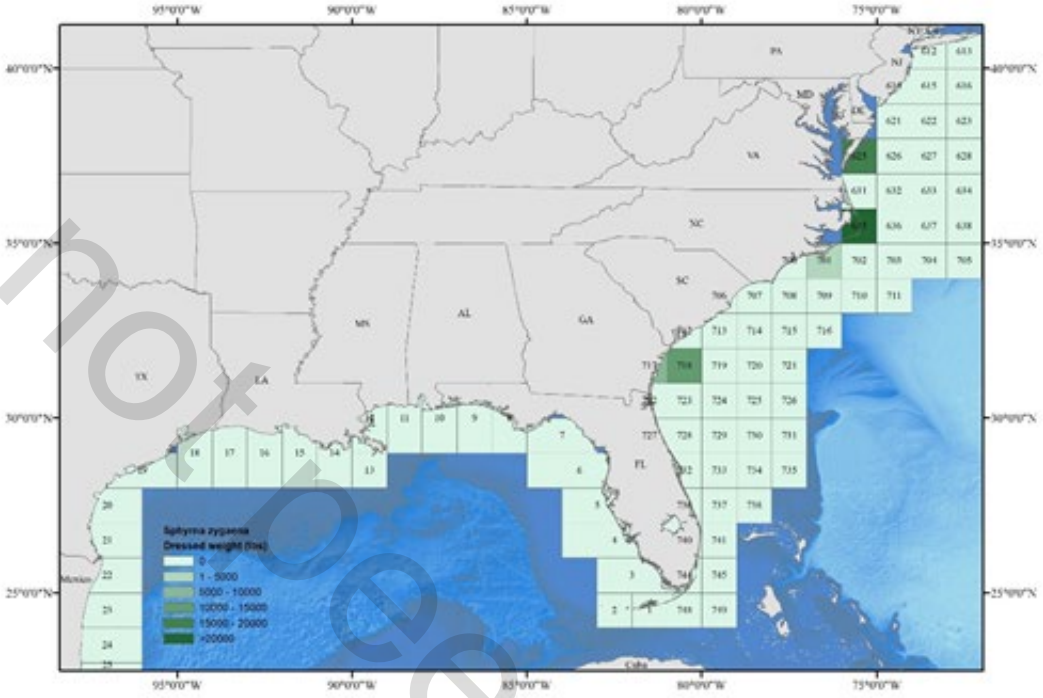


Figure 18. Total landed pounds (dressed weight) of great hammerhead sharks for 1991-2020 by catch area reported in the FINS database. The bottom panel shows the catch areas from west to east in the Gulf of Mexico and from south to north in the Atlantic.



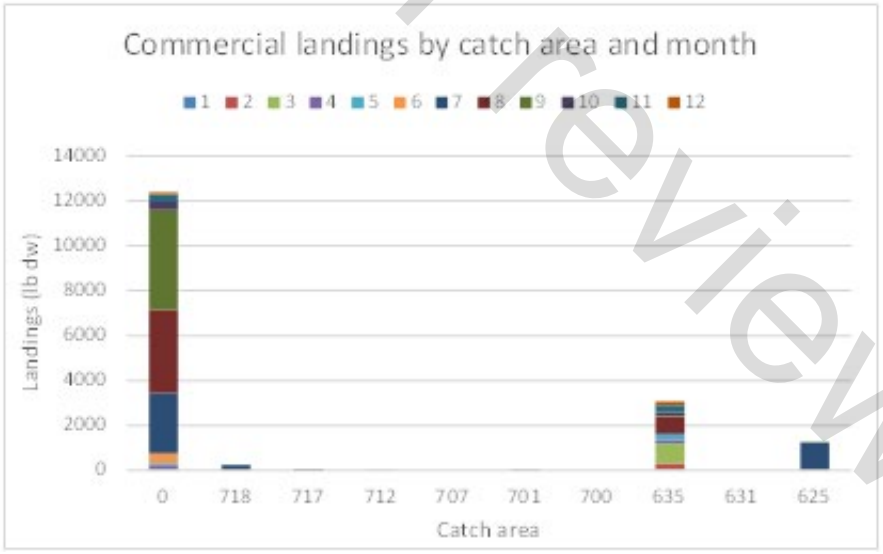


Figure 19. Total landed pounds (dressed weight) of smooth hammerhead sharks for 1991-2020 by catch area reported in the FINS database. The bottom panel shows the catch areas from west to east in the Gulf of Mexico and from south to north in the Atlantic.

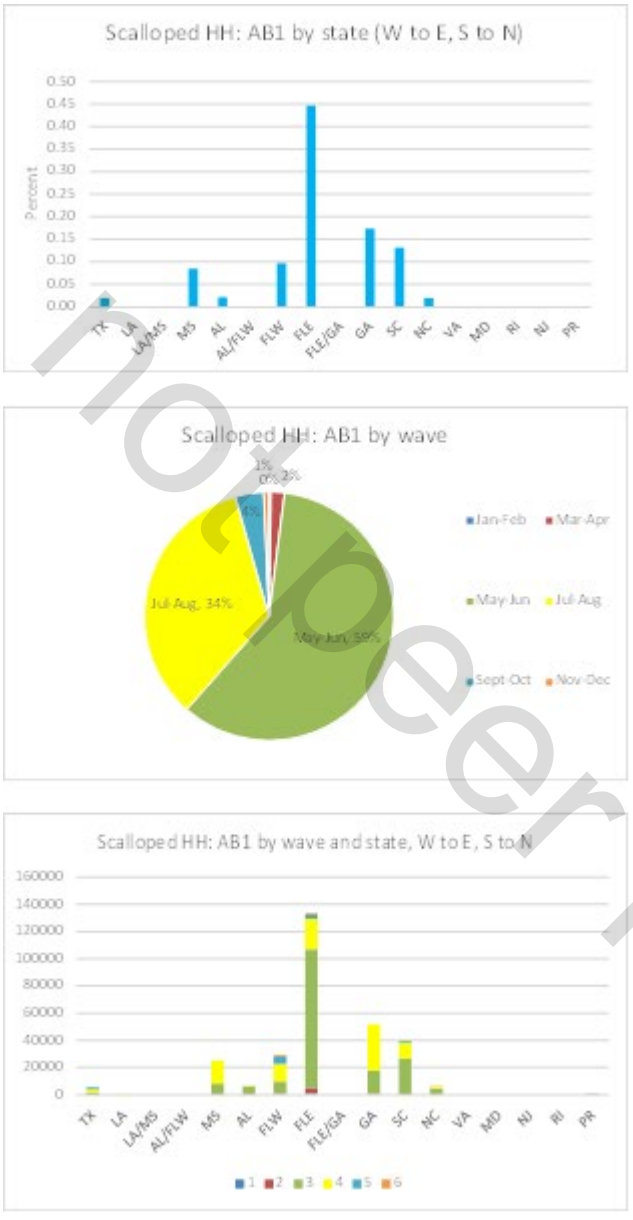


Figure 20. Catches (A+B1) of scalloped hammerhead sharks for 1981-2020 by state (from west to east in the Gulf of Mexico and from south to north in the Atlantic) (top), wave (middle), and state/wave (bottom).

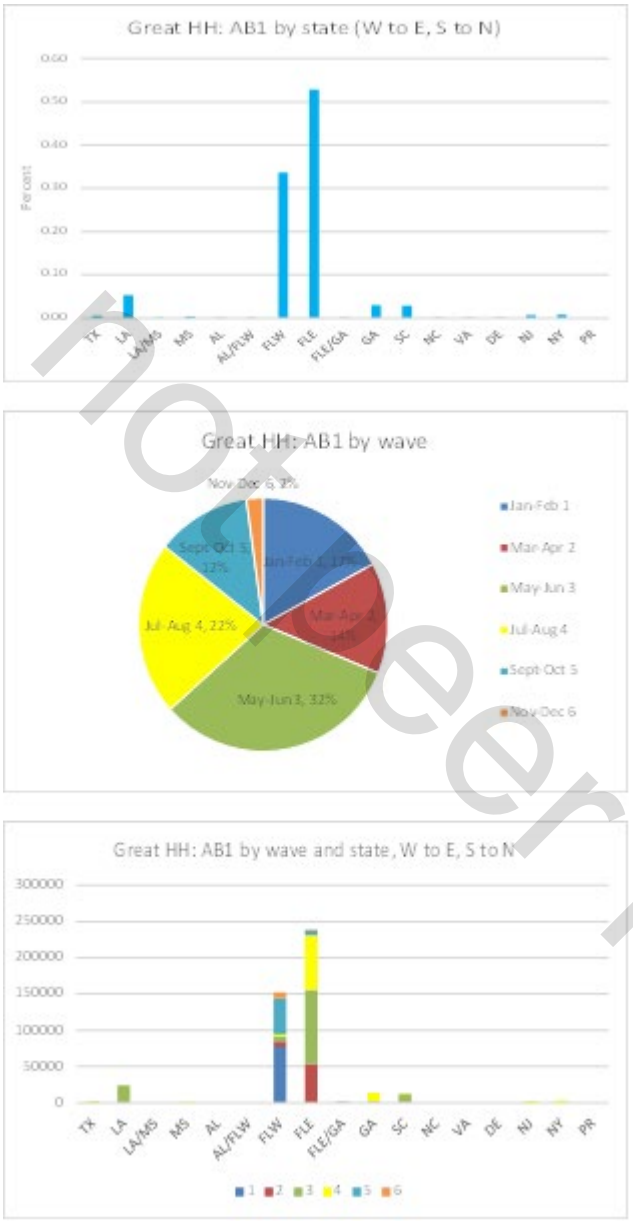


Figure 21. Catches (A+B1) of great hammerhead sharks for 1981-2020 by state (from west to east in the Gulf of Mexico and from south to north in the Atlantic) (top), wave (middle), and state/wave (bottom).

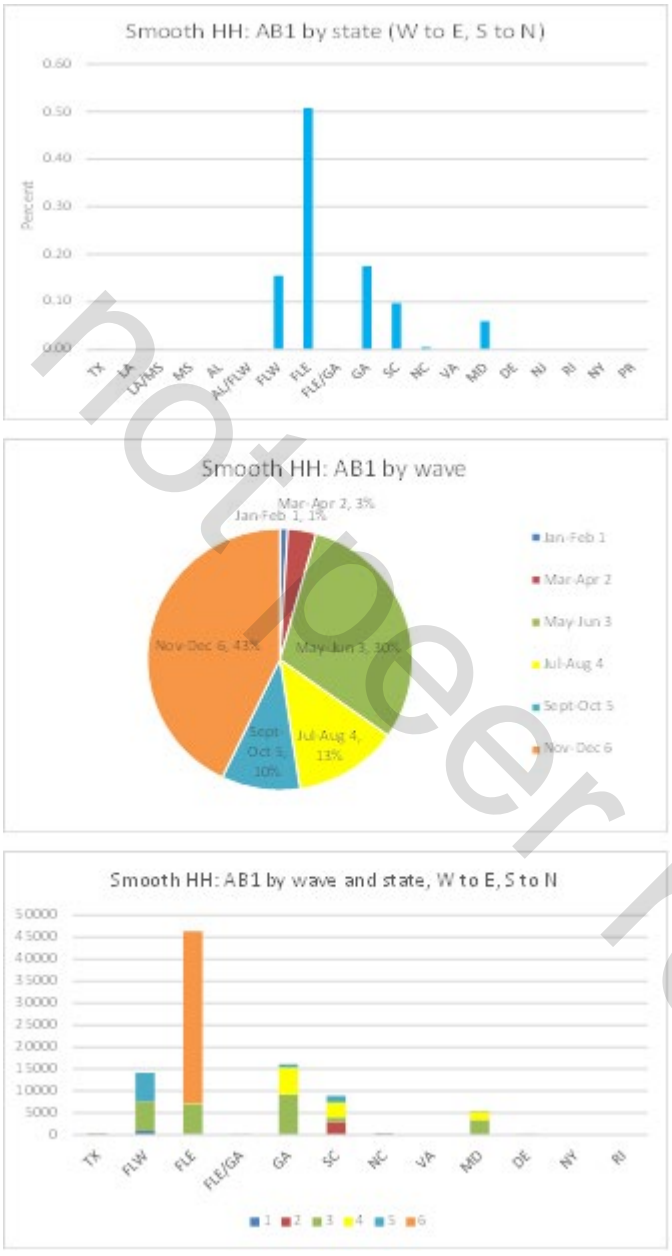


Figure 22. Catches (A+B1) of smooth hammerhead sharks for 1981-2020 by state (from west to east in the Gulf of Mexico and from south to north in the Atlantic) (top), wave (middle), and state/wave (bottom).